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1965

Properties and Uses of Pennsylvania Shales and Clays

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BULLETIN M 51

Properties and Uses of Pennsylvania Shales and Clays

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U. S. Bureau of Mines

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Dedicated to

HOWARD P. HAMLIN, 1913-1963

This volume is dedicated to Howard P. Hamlin in recognition of his services in developing and carrying out the program of raw material performance testing described in this volume. Mr. Hamlin pioneered in clay-shale testing techniques and his personal efforts contributed largely to the success of the Pennsylvania program.

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PROPERTIES AND USES OF PENNSYLVANIA SHALES AND CLAYS

ABSTRACT

To determine uses for Pennsylvania shales and clays, tests were performed on 151 samples from 41 counties and 51 geologic units. Of these samples, 137 have a potential for one or more of the following uses: brick, decorative brick, tile, floor tile, drain tile, chimney flue tile, refractories, lightweight aggregate, artware, pottery, filler, and pigmenting material. Rotary kiln and/or sintering tests were run on bulk lots of 25 samples which preliminary tests showed to have promise as lightweight aggregate.

The following variables were measured and are presented for each sample: (1) unfired properties such as drying shrinkage, water of plasticity, absorption, workability, and pH; (2) fired properties such as PCE and density changes; (3) quantitative X-ray mineralogy for quartz, mica, kaolinite, feldspar, and chlorite-vermiculite-montmorillonite; and (4) quantitative wet chemical analysis for 12 major elements. Geologic data are compiled for each sample.

Selected variables of the raw samples are quantitatively compared with both use and rock type. The most important variables for predicting the potential uses for sampled raw material are, in decreasing order of significance, (1) rock type, (2) mineralogy, (3) chemistry, and (4) unfired properties. Quantitative determinations of quartz, mica, kaolinite, total iron, the Fe^3/Fe^2 and K/Na ratios, CO_2, and possibly pH and water of plasticity are most useful in evaluating samples for decorative brick, refractories, and rotary-kiln lightweight aggregate.

INTRODUCTION

Shale and clay resources in various parts of Pennsylvania have been described in reports ever since the earliest geological investigations in the State were made. Most of the early descriptions of these resources, however, were limited to small, scattered areas and togther do not contain more than a fraction of the information concerning the State's shale-clay resources. The first report concerned exclusively with the clay and shale resources in Pennsylvania was by Hopkins (1898). Later, Ries (1903) wrote about the clays of the United States east of the Mississippi River and included a section on Pennsylvania.

In 1925, the Pennsylvania Geological Survey began a broader study of the clay resources in the State which resulted in a series of reports by Shaw (1928), Leighton and Shaw (1932), and Leighton (1926 and 1941). During 1942 and 1943, studies of the high-alumina clays in Pennsylvania were undertaken on a cooperative basis between the Pennsylvania Geological Survey and the U. S. Geological Survey. The results of these

studies were reported by Foose (1944). In 1943 and 1944, the U. S. Bureau of Mines conducted field examinations and beneficiation tests of high-alumina clays from deposits in central Pennsylvania (Sanford, 1949). Reconnaissance maps of the Mercer high-alumina clay horizon in Clearfield, Centre, and Clinton Counties were prepared by J. H. Weitz and R. C. Bolger in the course of a study of these clays from 1946 to 1950. The maps were later compiled and were published as a single map by the Pennsylvania Geological Survey (Map 12, 1964).

During the past several years, requests for information concerning the properties of shales and clays in Pennsylvania have increased. Many requests were made by industry and individuals for information on the availability of lightweight-aggregate materials which had not been considered in previous studies. Still others were interested in new information concerning the availability of shales and clays for other products. In response to this increased interest, the Pennsylvania Geological Survey entered into a cooperative program with the U. S. Bureau of Mines to evaluate the shales and clays in Pennsylvania for possible commercial use. Under the agreement, the Pennsylvania Geological Survey was responsible for planning and conducting the field work, for X-ray work on the samples, and for the correlation of field, geological, and laboratory data. The U. S. Bureau of Mines was responsible for making the appropriate laboratory tests and determinations of properties of the samples to indicate their potential uses.

In the spring of 1962, the investigation was initiated when a number of shale and clay samples were collected from outcrops, road cuts, and quarries. A total of 151 samples were collected in 41 counties from 51 different geologic units. Tests were performed on these samples at the Norris Metallurgy Research Laboratory of the U. S. Bureau of Mines, Norris, Tennessee. More than 65 of the samples tested showed a potential for expanded-aggregate material. From this group, 25 were selected for further expanded-aggregate tests. Bulk samples of these were obtained in the fall of 1963 and tested in a rotary kiln and/or a sintering hearth. These tests were conducted to determine if the materials could be utilized for production of lightweight aggregate by commercial methods.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the following persons who generously contributed their time to identify stratigraphic units and locate the best sample sites in areas in which they had special knowledge: B. H. Kent and S. P. Schweinfurth of the U. S. Geological Survey for assistance in Washington County; Dr. N. K. Flint of the University of

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Thanks are also due to many of the staff members of the Pennsylvania Geological Survey whose detailed geologic knowledge of certain areas made the task of selecting suitable sampling sites much easier. Acknowledgment is made of the rotary-kiln and sintering testing performed by M. V. Denny of the U. S. Bureau of Mines.

The authors are most grateful to all company officials who extended permission for the sampling of company properties.

GEOLOGY AND DISTRIBUTION OF SHALES AND CLAYS IN PENNSYLANIA

GEOLOGY

BY B. J. O'NEILL, JR.

The geologic map (Fig. 1) groups the rocks of Pennsylvania according to age, each color representing a period of time as indicated in the legend at the bottom of the map. The legend also lists the major types of rocks that occur within each of the groups as well as the more important rock and mineral products. Later in the text, each shale or clay sample is identified with a geologic unit (group, formation, and/or horizon) which belongs within one of these geologic periods or ages. For more detailed information concerning the distribution of rocks in Pennsylvania according to geologic formations, the reader is referred to the detailed Geologic Map of Pennsylvania which was published by the Pennsylvania Geological Survey in 1960 on a scale of 1:250,000 (Gray, Shepps, and others, 1960).

The rocks in Pennsylvania range in age from Precambrian, the oldest, to Quaternary, the youngest (Fig. 1). In general, except for the locations for the Triassic and the Quaternary deposits, the sequence from southeast to northwest across the State is from older to younger rocks.

Except in the northwestern counties, the rocks of the plateau region in the western part of the State are almost all of Mississippian, Pennsylvanian, or Permian age. The rocks in the plateau region are bent into a series of gentle folds with the beds essentially horizontal over large areas. The large area covered by Pennsylvanian rocks in the western part of Pennsylvania (Fig. 1) is a reflection of the near-horizontal attitude of the beds. The exposure of the underlying or older beds of Mississippian age is due to erosion processes which have worn away th overlying younger beds.

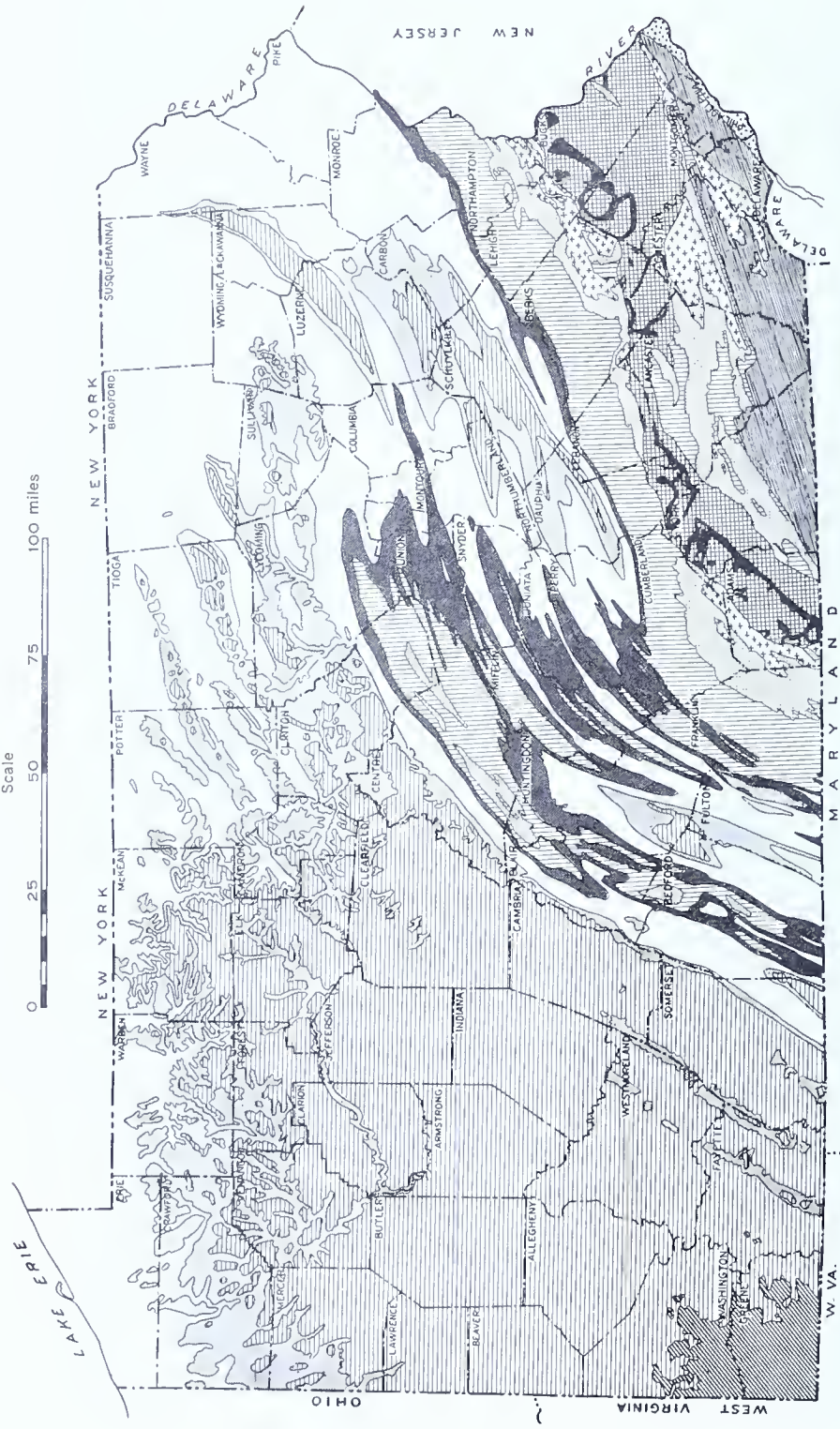


Figure 1. Geologic map of Pennsylvania.

The Appalachian Mountain physiographic region in central Pennsylvania is underlain by highly folded rocks ranging in age from Cambrian to Pennsylvanian (Fig. 1). The intense folding in this region is reflected in the complex pattern of narrow bands that repeat themselves by zigzaging as they trend across the State in a general northeast-southwest direction.

The southeast portion of the State is underlain largely by crystalline rocks and metamorphosed Cambrian and Ordovician sediments which are intensely folded and faulted. Triassic rocks occupy a belt running from Bucks County to Adams County. In the extreme southeastern corner of the State, a narrow strip of unconsolidated deposits of Quaternary age comprises the Coastal Plain province of Pennsylvania.

Areas of glacial deposits in northwestern and northeastern Pennsylvania do not appear in Figure 1, but are shown on the detailed Geologic Map of Pennsylvania (Gray, Shepps, and others, 1960).

TYPES AND DISTRIBUTION OF SHALES AND CLAYS

BY B. J. O'NEILL, JR.

For the purposes of this report the term shale is used collectively for indurated rocks containing clay-size particles and includes shale, claystone and underclay; for practical purposes of this report, a small number of samples of slate, phyllite, and schist are included. Nonindurated clay materials are referred to collectively as clays; these types include residual and glacial clays. Those persons who are unfamiliar with some of these rock terms are referred to the glossary in this report.

Rocks within the shale group occur throughout the State. Shale, claystone, and underclays are sedimentary rocks; on the geologic map (Fig. 1) they are found in every age group except the Quaternary, Precambrian, and Ordovician and/or Cambrian (see legend).

Underclays occur beneath coal horizons and are restricted mostly to rocks of Pennsylvanian age in the western plateau areas of the State. The metamorphic equivalents of shale—slate, phyllite, and schist—occur only in the southeastern portion of the State, within Ordovician to Cambrian age groups; metamorphic rocks of Ordovician age are restricted mostly to Northampton and Lehigh Counties.

Residual clays develop by weathering processes acting upon bedrock at the surface of the earth. They are commonly formed over impure limestones, rocks of the shale group, and some igneous rocks, and may be found at any place where these rock types occur except in the glaciated areas.

In the glaciated regions, which are located in the northwestern and northeastern parts of the State, clay-rich materials may be found in the form of lake deposits and till. Most tills have a content of coarse materials which may limit their use. In the northwestern part of the State, the only tills having a potential for use as clay material are the Lavery, Hiram, and Ashtabula tills (Shepps and others, 1959, p. 50 and Pl. 1).

CLAY PRODUCTION IN PENNSYLVANIA

BY R. D. THOMSON

The clay industries of Pennsylvania play a vital role in the economy of the Commonwealth, as well as the Nation. Since 1900, clay production has ranged from a low of 122,000 tons in 1902 to a high of 4,413,000 tons in 1956. Figure 2 gives the annual production in tons from Pennsylvania mines from 1900 through 1962.

In recent years, production of fire clay has been confined principally to the central and southwestern counties. The counties south of a line from Clinton County to Lawrence County and west of a line to Huntingdon County have been the most productive in the past 10 years. Another area lies in the southeastern part of the State in Lancaster and Montgomery Counties. In 1962, fire clay was mined in 18 counties and was produced predominantly in Clearfield, Armstrong, Lawrence, Jefferson, and Beaver Counties. The fire clay was used principally in manufacturing fire brick and block and structural clay products; small quantities were used in producing a variety of other refractories and as a filler in rubber and pesticides.

Miscellaneous clays are distributed widely in the State and in recent years have been produced in 25 or more counties. In the western part of the State, output of miscellaneous clays has come from three areas. The largest area lies in the center and southwestern part of Pennsylvania and consists of Lawrence, Butler, Clarion, Jefferson, Beaver, Allegheny, Armstrong, Washington, Westmoreland, Greene, and Fayette Counties. The second area comprises Clearfield, Clinton, Cambria, and Blair Counties. McKean County is the third western area. In the east, miscellaneous clays have been produced in Snyder, Northumberland, Columbia, Luzerne, Carbon, Monroe, Schuylkill, Dauphin, Berks, Bucks, Adams, York, Lancaster, Chester, and Montgomery Counties.

Miscellaneous clays were produced from 25 counties in 1962. Schuylkill County was the leading producer, followed in decreasing order by Berks, Lawrence, Northumberland and Dauphin Counties. The miscellaneous clays were used mostly in producing structural clay products; smaller

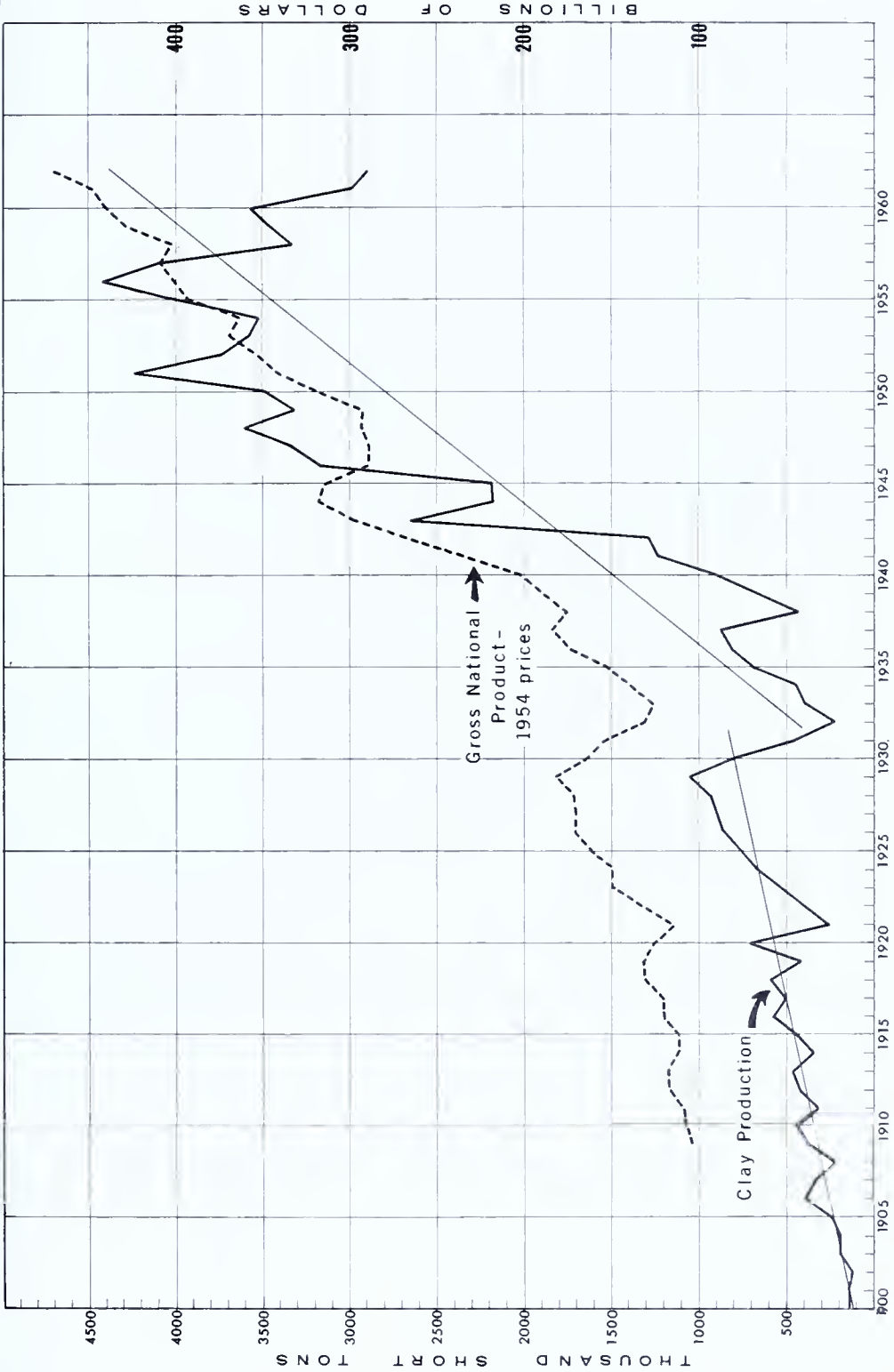


Figure 2. Pennsylvania clay sold or used (1900 to 1962).

quantities were used in manufacturing portland cement, art pottery, flower pots, lightweight aggregates and as a filler in linoleum.

Kaolin has been produced from four separate areas at one time or another. In recent years, kaolin has been produced in Cumberland and Blair Counties, with Cumberland County being the leading producer. Most of the kaolin was used as a component in portland cement; the remainder was used in fire brick and block.

Clay mines are numerous, and range in size from those producing only a few hundred tons a year to those producing thousands of tons annually. Usually, the output of the small mines is sold directly to a consumer. The larger mines are captive operations, that is, their output goes directly to the consuming plant of the parent organization. In 1962, clay was produced by 85 companies from 126 operations, of which 111 were exclusively clay mines. Other operations were in conjunction with coal and limestone mining. Of the clay mines reported, 89 were open-pit and 22 underground.

The level of clay consumption over the years has been determined by the rates of steel and glass production and of residential and nonresidential construction. Structural clay products such as building brick, sewer pipe, and drain tile have required the major portion of the annual supply of miscellaneous clays. Portland cement also has been a large consumer of miscellaneous clay. Refractories and structural clay products have been the major consumers of fire clay. The short-term demand for clay produced in Pennsylvania should continue to grow or decline at about the same rate as the volume of activity of these major consuming industries. Over a longer period of time, changes in technology, architectural styles, and new uses also will affect the pattern of clay consumption.

Lightweight aggregate is produced in Pennsylvania in two plants, one located near Tamaqua and the other at Bangor. The Lehigh Materials Company, a subsidiary of Warner Company, began operating a sintering plant in 1948, utilizing carbonaceous shale obtained from local anthracite mines (Brick and Clay Record, 1957). The second plant, operated by Pennsylvania Lightweight Aggregates, Inc., began commercial operations in 1962, employing a rotary kiln, using slate obtained from local waste piles. The sintered aggregate has been marketed in the northeastern States, principally in the New York-New Jersey Metropolitan area; the rotary kiln product has been marketed mainly in New Jersey and eastern Pennsylvania.

Lightweight aggregates are important materials to the construction industry. It is anticipated that use of lightweight aggregates will be augmented by their being used by a greater percentage of the construction industry, by the increased diversification in use, and diminishing supply

Table 1—*Clays sold or used by producers, by kinds and uses*[1].
(Short tons)

FIRE CLAY	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Refractories											
Firebrick and block	1,125	836	[3]851	958	1,090	932	598	716	837	684	611
Fire-clay mortar	38	28	30	30	28	[6]	13	21	21	14	13
Foundries and steelworks	99	82	91	118	137	95	66	102	108	58	57
Clay crucibles	....	....	....	....	....	....	9	[6]	20	13	2
Miscellaneous refractories	....	60	64	140	159	[6]	[6]	[6]	[6]	[6]	[6]
High-alumina brick	....	6	7	[6]	8	[6]	4	[6]	[6]	[6]	[6]
Structural clay products	692	643	826	903	995	896	773	795	748	606	517
Undistributed	[3, 4]38	[4]48	[4]32	[4]12	[4]26	[4]169	[4]82	[4]170	[4]124	[4]88	[4]76
TOTAL[2]	1,992	1,703	1,902	2,160	2,443	2,091	1,544	1,803	1,858	1,465	1,276
MISCELLANEOUS CLAY											
Pottery and stoneware	....	13	14	[6]	[6]	[6]	[6]	[6]	12	[6]	[6]
Refractories											
Firebrick and block	....	....	2	....	....	....	[6]	1	[6]	....	....
Foundries and steelworks	18	14	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]	[6]
Structural clay products	1,537	1,614	1,439	1,504	1,572	1,590	1,414	1,310	1,306	[6]	1,247
Cement	175	217	155	170	205	201	232	202	152	136	[6]
Lightweight aggregate	....	....	....	117	[6]	126	104	[6]	[6]	[6]	[6]
Paint fillers or extenders	1	7	1	1	1	1	....	....	....	....	....
Undistributed	[5]9	[5]8	[5]12	[5]29	[5]193	[5]29	[5]23	[5]121	[5]229	[5]1,398	[5]371
TOTAL[2]	1,739	1,872	1,623	1,821	1,970	1,947	1,773	1,634	1,699	1,535	1,617

[1] Bureau of Mines.
[2] Owing to rounding, individual items may not add to total shown.
[3] Includes kaolin.
[4] Includes cement (1952-54), miscellaneous fillers (1953, 1960-62), floor and wall tile (1959-60), glass refractories (1953-62), pottery and stoneware (1952-58), and items indicated by footnote 6.
[5] Includes miscellaneous fillers (1952-62), mortar (1952), tile (1952-62), and items indicated by footnote 6.
[6] Included with "Undistributed" to avoid disclosing individual company confidential data.

of natural aggregates and by-product aggregates in some areas. Major markets exist in the metropolitan areas of Pennsylvania and adjacent states. A combination of suitable raw material, adequate reserves, and favorable transportation costs should give impetus to the growth of clay and shale lightweight-aggregate production in Pennsylvania.

SAMPLING AND TESTING PROCEDURES

GENERAL STATEMENT

The primary purpose of this study was the evaluation of shale and clay samples collected throughout the State from as many geologic horizons as possible; 151 samples from 51 geologic units in 41 counties were collected by B. J. O'Neill, Jr. of the Pennsylvania Geological Survey. The locations for the 151 shale and clay samples are shown in Figure 5. Figure 5 and detailed descriptions of these locations are included in the Individual Sample Data section of this report.

SAMPLING PROCEDURES

BY B. J. O'NEILL, JR.

The sampling program was divided into two phases. The first phase consisted of collecting 10 pound samples at all sample locations. The location for each sample was plotted on a topographic map and notes concerning the local geology were made. Colors of the collected materials were determined with the Munsell Rock-color Chart. The samples were split and one half was sent to the Norris Metallurgy Research Laboratory of the U. S. Bureau of Mines in Norris, Tennessee for physical and firing tests. The other half was retained on file at the Pennsylvania Geological Survey in Harrisburg, Pennsylvania. The test results indicated that more than 65 samples showed a potential for lightweight-aggregate material. From this group, 25 were selected for further aggregate tests.

The second phase of the sampling program consisted of collecting three 100-pound bulk samples from each of the 25 selected locations. The bulk samples were shipped to the Norris Laboratory for rotary kiln and/or sintering hearth tests.

Wherever practical, channel samples were taken. In cases where channel samples were not possible, grab or composite samples were obtained.

PHYSICAL TESTS

BY R. D. THOMSON

General Statement

The wide variety of products made from industrial shales and clays places them in a class of a major industrial raw material. Many clays can be used in the crude state, much as they come from the deposits. Other shales and clays must be beneficiated or refined to remove objectionable impurities. For each end use, clay must possess certain properties, and what is considered a critical property in a shale or clay for one product may be wholly unimportant in another. To test each sample for all uses would be impractical, and, fortunately, is unnecessary for preliminary appraisals. The preliminary testing is exploratory and gives clay type, properties, and possible uses. Such evaluations are valuable in that they indicate the possible uses of the shale or clay and whether the material warrants further test work.

General Testing Procedures

For the preliminary tests, a two-pound representative sample is dried at 230° F and ground so that 100 percent passes 20 mesh. One hundred grams of the dried clay is mixed with water to form a plastic mass. The working properties of the clay are noted. Small test specimens (approximately 1½″ X 2½″ X ¼″) are made from the plastic mass, marked for shrinkage, dried at 150° F for 12 hours and at 230° F for an additional 12 hours. Six of the dried specimens are placed in an electric muffle kiln and the temperature is raised slowly to prevent disintegration when the mechanically and chemically combined water are released. Approximately three hours are required for the kiln to reach 1800° F. Test specimens are removed from the kiln at 1800, 2000, 2100, 2200, 2300, and 2400° F, after a 15-minute soak at each indicated temperature. About 4 hours are required to cover the range of 1800° to 2400° F; these temperatures cover the range encountered in most ceramic firing and are adequate for general appraisals.

The method described for making the test specimen is essentially the soft mud process and, in comparison with the stiff mud process normally used in commercial production, the quantity of water used for achieving plasticity is higher. Firing shrinkages also are higher since the clay is not de-aired, and the pressure used in forming is much less.

From the slow-firing tests, the following data are accumulated: workability, plasticity, pH and soluble salt determinations, water of plasticity,

drying and firing shrinkage, color (fired and unfired), percent absorption, drying characteristics (warping or cracking), apparent specific gravity, and hardness.

On the basis of these data, clays can be evaluated for the following ceramic and non-ceramic uses:

Ceramic	*Non-Ceramic*
Whiteware	Fillers for plastic
Structural products	Paint, paper, rubber, etc.
Refractory products	Abrasives
Artware or pottery	Oil clarifiers
Lightweight aggregate	Foundry molds
	Drill muds
	Pigments

A general discussion of the criteria used for judging the materials for possible commercial uses is given on the following pages, while specific details on methods and procedures used in testing clays are described in Bureau of Mines Bulletin 565 (Klinefelter, 1957). A.S.T.M. designations of specifications and tests related to structural clay products and refractories are given under References.

Lightweight Aggregate

Lightweight aggregate is produced by either the rotary-kiln or sintering method. The properties of the raw material determine the method of processing. For the rotary-kiln process, the raw materials should dry readily without undue disintegration and show good expansion when heated rapidly. For the sintering process, the raw materials should vitrify at 2300° F or lower with slight expansion, and the particles should have a slightly glazed exterior.

Quick-firing Tests.—The quick-firing tests are used to determine the bloating range of clays and shales within the range of commercial working temperatures, starting just under bloating and continuing until overbloating or sticking occurs. Five pounds of the sample are dried overnight at 230° F, crushed in a roll crusher or jaw crusher (set at ½ inch) and a screen analysis is made of the crushed material (Hamlin, 1962). Twenty grams (–½ to +¼ inch size) is placed on a refractory slab or boat, inserted into a preheated muffle kiln (1800° F) for 15 minutes, and then removed. The kiln temperature is raised in 100° F steps, and subsequent samples are processed in the same manner until 2400° F is reached or until the material is overfired and becomes sticky and melts. The following data are obtained from the quick-firing tests: weight per unit volume, percent absorption, particle size, crushing and drying char-

Table 2—*Criteria used in evaluating clays and shales for lightweight aggregate.*

	Rotary Kiln Process	*Sintering Process*
Unfired properties		
Drying characteristics	Dry readily and show only slight disintegration.	Not critical, water used to pelletize before firing.
Dry strength	Must be sufficient for proper sizing when crushed for kiln feed.	Not critical
Crushing characteristics	–8 mesh material should not exceed 20%, see additional discussion.	Not critical except where particles tend to be thin and platy.
Fired properties		
Firing range	1800-2200°F	Vitreous and glazed between 2200-2300°F
Bloating range	Minimum 100°F, 200° preferred	Not critical
Density	75-45 lb/ft^3	75-45 lb/ft^3
Expansion	Gradual weight decrease through bloating range	Slight
Absorption %	0-18.0 at best bloating temp.	0-6.0
Color	Light reds to light grays preferred although color not too critical.	Light red-grays preferred although color not too critical.
Strength	Determined by concrete performance test	Determined by concrete performance test.

acteristics, and bloating properties. Table 2 gives the general criteria for judging clays and shales as lightweight aggregate, describing their unfired and fired properties for both the rotary-kiln and sintering processes. On the basis of the quick-firing data, material that bloats can be classified for its lightweight-aggregate quality as follows:

Excellent—An aggregate which exhibits such factors as low specific gravity, low absorption, uniform particle shape and size, thick skin, high crushing strength, uniform pores, and acceptable temperature range.

Good—An aggregate that has a combination of fair and excellent properties.

Fair—An aggregate that has properties which are near the undesirable limits.

Although the quick-firing tests will give useful data in appraising clays or shales as lightweight aggregates, the final evaluation is based on data

obtained from rotary-kiln testing or sintering tests designed to approximate commercial operating conditions. Specific details on the procedures used in testing clay or shale in a 14-foot test rotary kiln are given in Bureau of Mines Information Circular 8122 (Hamlin, 1962, pages 15-22).

Crushing Characteristics.—Size and shape of the particles of the kiln feed are of considerable importance in rotary-kiln processing because they influence the behavior of the material as it passes through the kiln and the quality of the expanded aggregate. As a general rule, if the kiln feed contains an excess of 10 percent minus 8 mesh particles, sticking will occur because the fines will overfire and become sticky, since the heat penetrates the smaller sizes much faster than it does the coarser material. Excessive fines in soft clays are not a serious problem because they can be removed by screening and stockpiled until they are moist enough to compact sufficiently for reuse. The fines from harder materials do not compact naturally, and they often are discarded as waste material. However, shale and slate fines can be pelletized. If the screen analysis of a sample shows excessive "fines" (above 20 percent), a further study of the crushing characteristics should be made to see if different techniques will decrease the percentage of fines.

The influence of particle thickness on the expansion characteristics can best be explained by the bloating process. Where a particle expands under heat treatment, the exterior becomes pyro-plastic, or melted, enough to entrap the gases generated by the decomposition of the various compounds on the interior. Thin particles tend to heat all the way through, and the gas-producing compounds are decomposed before the exterior becomes pyro-plastic enough to entrap the gases that produce the expansion.

While it is possible to establish the proper retention time required to expand a given material by laboratory testing, commercial-size rotary-kiln tests are essential to show the effect of particle shape on the processing characteristics.

For clay or shale that is to be sintered, crushing characteristics are not critical because the material is mixed with finely ground coal or coke and pelletized before processing.

Firing Characteristics.—For rotary kiln processing, a long range is desirable between the temperature at which the clay or shale begins to expand and the sticking temperature. Good bloating material will bloat over a temperature range of 200° F or more. Materials with less than 100° F bloating range are not suitable for lightweight aggregate if the rotary-kiln method of production is to be used.

The rate of weight loss during bloating is roughly indicative of the quality of the aggregate. Good aggregate will show a gradual decrease

in weight per unit volume as the temperature increases. As a general rule, materials that show abrupt weight changes are not amendable to the rotary-kiln method of processing.

The laboratory testing and evaluating of material for lightweight aggregate has proved to be of greater value for rotary processing than for sintering. The tests for determining sintering properties are less definitive, and in most cases the true evaluation can only be accomplished by making small-scale sintering tests.

Structural Clay Products

The nomenclature of structural clay products varies from one section of the country to another; processing terms are often added to the name, and the type of application also may be used with the name. Examples which show the use of application and processing terms with the product name are: fireplace tile, chimney flue tile, decorative face brick, hollow wall tile, back-up brick, inlaid tile, sand finished brick, glazed brick, pressed brick, scored brick, etc. Floor tile not only varies in size from one section of the country to another, but it is known by varying names—in the South it is often called quarry tile; in the West, patio tile; and in other sections, ceramic floor tile.

Structural clay products are made using a wide variety of shale and clay raw materials. The properties of these materials vary in importance with the product and the method of processing. While the dry press and soft mud processes are sometimes used, the most common forming method used is the stiff mud process. In this process, workability is the most important property of the raw material. Since the clay is extruded under pressure, it should flow smoothly in a column from the die without undue lamination or other defects. Excessively plastic clays tend to laminate when extruded while nonplastic clays will not extrude in a smooth column.

The clay must dry uniformly at a reasonable rate without warping and cracking. Often fine sand or grog is added to clays to improve the drying rate. Such additions also decrease the drying and firing shrinkages.

Clays should develop adequate "green" strength so that the ware can be handled in the unfired wet and dry state. However, the importance of this property has declined to some extent due to the development of organic binders which makes it possible to utilize many raw materials previously considered unsuitable.

The importance of fired color varies from one structural product to another. Through the use of pigments, fired colors can be controlled and more desirable colors can be produced.

Blending clays to produce structural products has become a fairly common practice in the past few years. Each clay is selected because of certain desirable properties. For an example, one clay may have ex-

Table 3—*Criteria used in evaluating clays and shales for structural clay products.*

	Common brick	*Face brick*	*Decorative brick*	*Hollow tile*	*Wall tile*	*Drain tile*	*Roofing tile*
Unfired properties							
Workability	Fairly plastic to plastic	Fairly plastic to plastic	Fairly plastic to plastic	Plastic to very plastic and smooth	Plastic to very plastic and smooth	Plastic to very plastic and smooth	Plastic to very plastic and smooth
Water of plasticity	15 to 40	15 to 40	15 to 40	0 - 35	0 - 35	15 - 40	0 - 35
Green strength							
Wet	Low to high	Low to high	Low to high	Average to high	Average to high	Average to high	Average to high
Dry	Low to high	Low to high	Low to high	Average to high	Average to high	Average to high	Average to high
Drying characteristics	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking
Drying shrinkage %[1]	0 - 12	0 - 12	0 - 12	0 - 8	0 - 8	0 - 8	0 - 8
Fired properties							
Maturing temp. °F	1800-2000	1800-2200	1800-2200	1800-2100	1800-2100	1800-2000	1800-2200
Hardness	Very hard to steel hard	Steel hard	Steel hard	Steel hard	Steel hard	Very hard	Steel hard
Absorption %	Up to 20	Up to 15	Up to 15	Up to 15	0 - 10	0 - 12	0 - 10
Shrinkage %[1]	0 - 10	0 - 10	0 - 10	0 - 10	0 - 10	0 - 8	0 - 8
Color	Reds to browns	Reds, browns, buffs, creams	Unusual colors, pinks, grays, etc.	Not critical usually red, brown-red, buffs	White, buffs, reds, creams	Buffs to red-browns	Buffs, reds, browns
Scumming	Slight	None	None	Slight	None	Slight	None

[1] Commercially, total for shrinkage of unfired and fired product should not exceed 15 percent.

Table 3—*Criteria used in evaluating clays and shales for structural clay products (continued).*

	Floor tile	*Flue tile*	*Architectural Terra cotta*	*Sewer pipe*
Unfired properties				
Workability	Plastic to very plastic and smooth	Plastic to very plastic and smooth	Very plastic and smooth	Plastic to very plastic and smooth
Water of plasticity	0 - 35	15 - 40	18 - 35	0 - 35
Green strength				
Wet	Average to high	Average to high	Average to high	Average to high
Dry	Average to high	Average to high	Average to high	Average to high
Drying characteristics	No warping or cracking	No warping or cracking	No warping or cracking	No warping or cracking
Drying shrinkage%[1]	0 - 8	0 - 8	Up to 8	0 - 8
Fired properties				
Maturing temp. °F	1800-2200	1800-2400	2000-2200	1800-2100
Hardness	Steel hard	Very hard	Steel hard	Steel hard
Absorption %	0 - 20	0 - 20	8 - 25	0 - 8
Shrinkage %[1]	0 - 8	0 - 8	0 - 8	0 - 10
Color	Reds, buffs, dark browns	Buffs, reds, and red-brown	Reds, buffs, gray-buffs, off-whites	Reds, red-brown
Scumming	None	None	None	None

[1] Commercially, total for shrinkage of unfired and fired product should not exceed 15 percent.

ceptionally good working properties, but the shrinkage is high and the fired color poor; another may have poor working characteristics, but low shrinkage and a good color. By combining the two clays, a more satisfactory product can be produced.

The criteria used for evaluating materials to manufacture structural clay products are given in Table 3. For this report, tiles have been subdivided into four types: floor tile. "tiles", flue tile, and drain tile. Although almost all samples usable for tile are within the ranges listed in Table 3 and hence cannot be easily classified on this basis, only seven samples are listed with more than one potential tile use. A subdivision of tiles into these four types, at least in part, was the result of experienced judgment by the analysis. However, it should be noted that there are differences among these types, e.g., in pH and percent drying shrinkage (see Fig. 20), so that this judgment appears to have some validity.

Refractory Clays

The most important property to be considered in appraising refractory clays is refractoriness. Other properties must be considered but vary in importance with the method of fabrication and the specific use. Blends of clays are used in making most refractory products and the ware may be formed by dry pressing, extruding, casting, or hand molding. The desirable properties of the blending materials, such as plasticity, green strength (wet and dry), and drying characteristics, will vary to some extent, depending on the method of fabrication used.

Some of the more common names associated with refractory clays are flint, semiflint, semiplastic, plastic, high-alumina, coal-measure fire clays, and refractory bond clays. Such names as sagger, stills, hot tops, or high duty, intermediate duty, and low duty are used by the trade to indicate a refractory clay that is suitable for a specific use or class of refractory.

Table 4—*Standard classification of fireclay refractory brick*[1].

Class	*Pyrometric cone equivalent*
Super duty	33
High duty	31 - 32
Intermediate duty	29 - 31
Low duty	19 - 29

[1] ASTM C27-41.

In a preliminary evaluation of a refractory clay, the general testing procedure distinguishes the plastic clays from the nonplastic clays and gives other properties such as shrinkage, absorption, and apparent specific gravity. The most essential test for these clays is the pyrometric

cone equivalent (PCE) test. This test will distinguish refractory clays from nonrefractory materials and also indicate the temperatures at which the clay can be used.

The criteria given in this report for appraising the refractory clays are based largely on the pyrometric cone equivalents as shown in Table 4.

Pottery and Stoneware

In evaluating shales and clays for pottery and stoneware, workability and fired color are the most critical properties. The ware is formed either by slip casting, jiggering, or throwing. If the ware is formed by throwing or jiggering, the raw material must have above average plasticity. As a general rule, the more plastic materials have better slip casting properties since they are usually finer grained than the less plastic ones.

Although pottery is sometimes made from a single clay, most of it is made from blends of clays and fluxing materials. Thus the working characteristics, firing characteristics, and maturing temperatures can be more or less controlled by selecting the proper clays for the blend.

The principle criteria for evaluating clays for pottery and stoneware are listed in Table 5.

CHEMICAL ANALYSES

BY M. G. JARON

Samples collected in the field were sent to the U. S. Bureau of Mines where they were crushed for physical testing. After testing, a portion of each sample was retained by the Pennsylvania Geological Survey for X-ray and chemical analyses. A minimum twenty-five gram sample was sent to Spectrochemical Laboratories, Inc., Pittsburgh, Pennsylvania, for wet chemical analysis.[1]

Data from the chemical analyses are presented in a standard manner except that all of the CO_2 content of samples marked by an asterisk (*) is derived from CO_3=. The L.O.I. (loss on ignition) content for these samples consists of CO_2 from C, H_2O+, and H_2O-. On samples NOT marked by an asterisk the CO_2 is from both C and CO_3=. The L.O.I. content for these samples consists of CO_2 from C and CO_3=, H_2O+ and H_2O-. In all cases the ignition temperature was 900° C.

[1]One duplicate sample was sent to serve as an indication of analytical reproducibility. The results of this duplicate analysis are:

Fe_2O_3	FeO	TiO_2	CaO	MgO	Al_2O_3	SiO_2	L.O.I.
7.17	.32	.84	.16	.92	15.55	64.90	6.10
7.51	.08	.84	.16	.87	15.60	64.90	6.16

K_2O	Na_2O	CO_2	S	H_2O+	H_2O-
3.50	.50	1.43	.016	3.71	.96
3.38	.42	.40	.02	4.81	.95

Table 5—*Criteria for evaluating clays for pottery and stoneware.*

	Stoneware	*Earthenware*	*Artware*
Unfired properties			
Workability	Highly plastic and smooth working	Very plastic smooth working	Very plastic smooth working
Water of plasticity	Not critical	Not critical	Not critical
Green strength			
Wet	Above average	Average	Above average
Dry	Above average	Average	.....
Drying characteristics	Dry free from defects at normal drying rates	Dry free from defects at normal drying rates	Dry free from defects at normal drying rates
Drying shrinkage	Not critical	Not critical	Not critical
Fired properties			
Maturing temp. °F	2100-2300	1800-2200	1800-2100
Shrinkage %	Not critical	Not critical	Not critical
Absorption % (unglazed)	0-2	0-5	Not critical
Absorption % (glazed)	0-0	0-0	0-0
Color	Buffs and grays	Reds, browns, and buffs	Variety

QUANTITATIVE X-RAY MINERALOGY

BY D. M. LAPHAM

General Statement

Quantitative X-ray mineral analysis of the clays and shales of Pennsylvania was undertaken for two reasons: 1) to correlate mineral content and potential use in the hope of establishing criteria useful in the future exploitation of these deposits, and 2) to obtain basic information concerning mineral variation in Pennsylvania shales and clays. Any correlation between use and mineral variation will be approximate because other factors such as texture, grain size, and certain critical chemical elements will exert a significant influence upon the utility of a clay or shale. However, certain mineral components are influential and their quantitative limits for specific rock types and use categories can be defined even though imprecisely. Mineral-composition data about particular geologic horizons will benefit not only research programs, but also diverse industries interested in the commercial possibilities of Pennsylvania's rock formations.

Mineral analysis by X-ray methods must be modified for rapid analysis of many samples in a short time, yet retain an accuracy sufficient to make correlations with use and geologic unit. Compromise procedures were adopted which in turn necessitated the solution of several problems with regard to both X-ray technique and interpretation. Because these solutions differ in many ways from those used previously in quantitative clay-shale analysis, they are discussed below in some detail in the hope that these procedures will be useful in other similar research projects.

Analytical Problems

Two different approaches have been used to solve the problems which arise by quantifying X-ray methods of mineral analysis. One is based upon the knowledge of X-ray theory and the interaction of X-rays with various materials, and the other is based upon an empirical, more practical approach. Generally, the theoretical approach has proved unsatisfactory and has led us to abandon the search for an absolute value of intensity of reflection, adopting instead an empirical method. However, several theoretical factors do influence accuracy and the choice of X-ray technique.

The atomic scattering factor may significantly influence measured intensities of reflection. This factor is dependent upon variations in the atomic density of a sample; in other words, the distance between atoms

in a crystal lattice and the atomic weight of these atoms. This scattering factor also varies with the angle of X-ray reflection. No correction was applied for this factor, partly because the samples studied contain approximately the same major minerals (quartz and illite) and the same minor minerals (kaolinite, feldspar, chlorite-vermiculite, and calcite) all of which have a similar order of magnitude for the atomic scattering factor. Thus this error should not be large.

A related, and more important source of error, is the absorption of X-rays by the sample. Absorption varies with atomic density and with degree of crystallinity, the latter being especially important for clay and mica minerals. Because the crystallinity of mica (illite) may affect the apparent amount by more than 50%, a correction factor has been devised (Lapham and Jaron, 1964) and is discussed below.

Crystallite size (the grain size of individual crystals) is another very important factor. As the crystallites become finer and the crystal lattice becomes distorted, the X-ray reflections begin to broaden. Optimum grain size is less than 10 microns (325 mesh = 44 microns) and should be uniform for all mineral components within a sample. In this project, all samples were ground to finer than 325 mesh, but there was no attempt made to obtain uniformly sized particles, partly because of time limitations, and partly because an attempt at uniformity may result in a concentration or lattice destruction of one particular mineral component. To offset this error, the intensities from a minimum of three runs per sample were averaged. However, size variation is probably the most significant source of error in the reported mineral percentages.

Preferred orientation enhances the reflection of those minerals with a good cleavage (micas and feldspar) relative to those with poor cleavage (quartz). Sedimentation and dispersal of the powdered rock samples on a glass slide enhance this preferred orientation and is the standard method used for quantifying minerals with good cleavage. However, because of the presence of poor-cleavage minerals and because sedimentation is a time-consuming procedure, this standard technique was discarded in favor of packing an aluminum sample holder by back filling. Back filling has these advantages over sedimentation: 1) less preferred orientation, 2) a greater total intensity of reflection resulting from greater packing density, and 3) a relatively planar and evenly distributed surface, both of which tend to reduce line broadening, yielding sharper peaks.

A relatively slow scan speed of 1° 2θ per minute and a low time constant of 4 were used to increase the accuracy of peak-height measurements.

In practice, when attempting quantification of samples which contain several minerals intimately mixed, additional problems arise in the interpretation of the resultant diffractometer traces. Various methods have been devised to correct for mineral interference, depending on the material studied and the accuracy desired. In any clay-shale analysis, the identification and separation of the clays, the micas, and the chlorites represent a major problem and the source of greatest error in arriving at mineral percentages. Often techniques other than X-ray have been introduced to separate, for example, the 7A chlorite peak from the 7A kaolinite peak. Montmorillonite has been expanded by ethylene glycol treatment to separate it from the 14A chlorites which do not expand with ethylene glycol. Other techniques such as staining and cation base exchange also have been used. Because of the rapid analysis desired, none of these were used here. Instead, corrections for each type of mineral interference were applied as discussed below so that all quantification could be performed by X-ray methods.

Illite is perhaps the most difficult mineral to deal with quantitatively because of extreme differences in crystallinity. The term "illite" has been variously used, but here refers to muscovite mica which has a 1M-d structure, or a 2M structure which has undergone degradation. The X-ray characteristics of such an illite are broad basal reflections (line broadening) instead of sharp peaks, and fewer strong reflections from planes other than basal spacings. Frequently, such an illite is believed to be leached of some of its normal K_2O content. In general, the greater the structural distortion present in the illite, the broader is the (001) basal reflection peak, and the lower is the peak height. Thus two rock units may have the same illite content, but if the degree of structural distortion of the mica is vastly different, then their peak intensities will also be vastly different. As a result, some means of measuring the crystallinity of the illite is necessary.

One method frequently used is to measure the area under an X-ray peak rather than the peak height because as the height decreases the peak width increases and the two are very nearly directly proportional. However, even with a planimeter, this is a slow process. A faster method was suggested by Freas (1962). He found that the ratio of the areas under the illitic mica (001) peak is one-third that of the area under the kaolinite (001) peak. This method presupposes 1) that interference between chlorite and kaolinite has been eliminated, and 2) that this kaolinite/mica ratio is a constant regardless of the crystallinity of the kaolinite (or mica). In order to find a more absolute system of measurement of the variability of mica intensity with degree of crystallinity, a more absolute intensity factor than the Freas' 3:1 kaolinite/mica ratio has been adopted (Lapham and Jaron, 1964). Briefly, this procedure

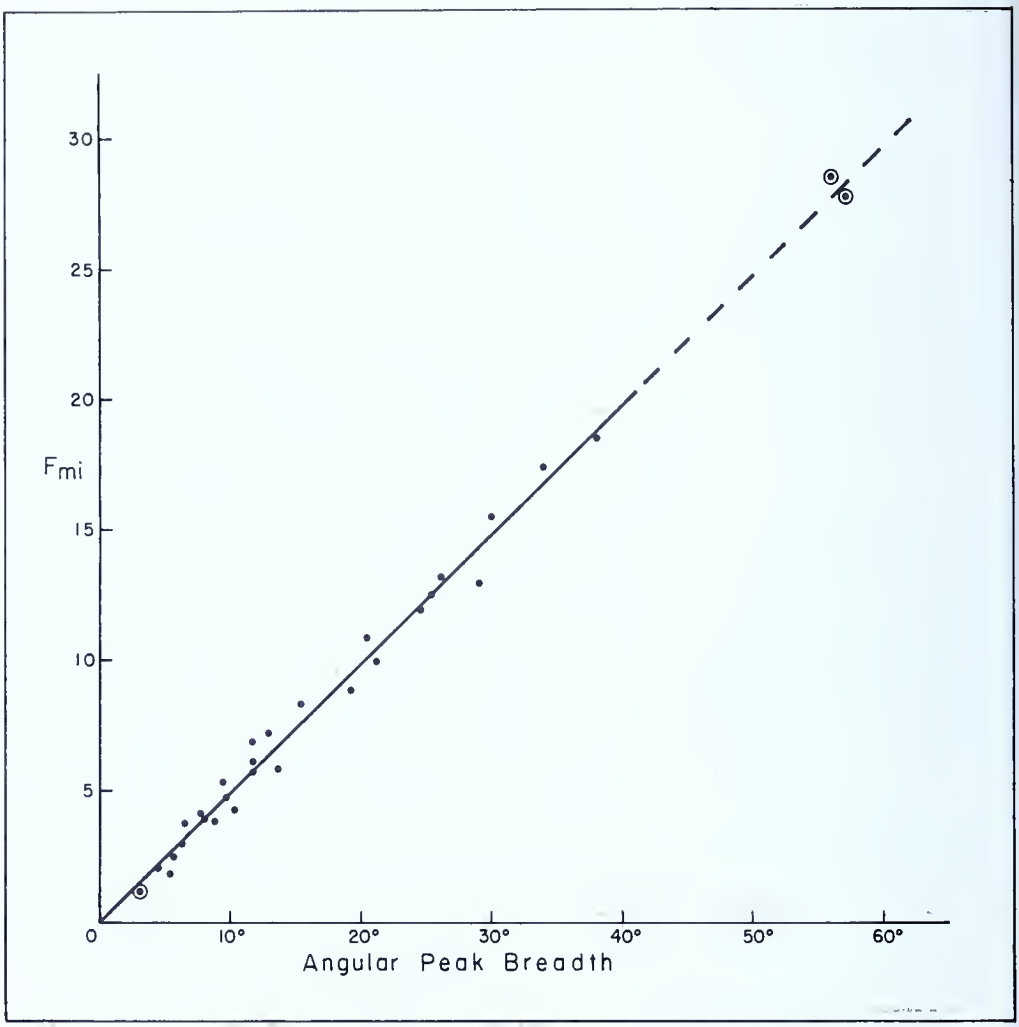


Figure 3. Multiplier factor (F_{mi}) for illitic mica versus the angular peak breadth of the X-ray diffraction (001) peak.

consists of measuring the angular breadth of the (001) peak by drawing tangents to the peak tip from the baseline on either side of the peak. This angle is related to the true intensity of the (001) basal spacing by the multiplier factor (F_{mi}) in Figure 3. Thus, the peak height of any illitic mica is related to an absolute intensity for well-crystallized muscovite mica by this intensity factor, and is independent of other minerals in the mixture. The derivation of this peak breadth-intensity factor curve has been discussed elsewhere (Lapham and Jaron, 1964). The equation for the curve is $F_{mi} = 0.494$ D, where D = the degrees angular (001) peak breadth of the illite.

Another problem of mineral interference involves the basal reflections of clay minerals at 7A and 14-15A. Three minerals, chlorite, vermicu-

ite, and montmorillonite, have a first-order reflection in the 14-15A egion. In addition, chlorite and vermiculite yield second-order basal eflections at about 7A, the same position as the kaolinite (001). For ccurate results these reflections must be separated as mentioned above. However, close approximations of their amount can be made without eparation where these minerals comprise ten percent or less of the total ample. Kaolinite intensity can be approximated by subtracting the ontribution from the second order reflections of the 14-15A components. For chlorite, the 7A peak is from 3 to 5 times the intensity of the 14A peak. For vermiculite the 14A is 10 to 20 times as intense as the 7A peak. Thus in practice, a mixture of about 4 chlorite to 2 vermiculite to 1 montmorillonite means a number of intensity units approximately equal to the number of intensity units of the 14-15A peak should be subtracted from the 7A peak to arrive at the intensity contribution of kaolinite. Unless independent evidence was available, this ratio of chlorite-vermiculite-montmorillonite was assumed to be present. Because of the numerous assumptions regarding the variation in intensity of any one of these 14-15A minerals and the ratio in which they are mixed, the kaolinite intensity is the least accurate, especially for high kaolinite percentages.

Quantitative Analysis Techniques

Samples collected in the field were sent to the U. S. Bureau of Mines and, after crushing, a part was retained by the Pennsylvania Geological Survey for chemical and X-ray analysis. The X-ray portion of the sample was ground in a mortar and pestle for approximately 15 minutes, or until the majority of the sample was finer than 325 mesh (44 microns). Although this is too coarse to yield ideally reproducible intensities, continued grinding could result in the destruction of the silicate mineral lattices which would reduce the intensity of reflection. Thus this procedure was effected as a compromise. The sample was then backfilled in an aluminum holder placed face down on a clean glass slide. An attempt was made to use the same packing pressure for each sample. Variations in packing did not affect the observed intensity by more than 5 percent. Three runs of each unknown were averaged to use in calculating the mineral percentages. All diffractometer traces were made with a Norelco diffractometer at a Scale Factor of 8, a Multiplier of 1.0 and a Time Constant of 4 and a run at 1° 2θ per minute with a 1° slit. This was necessary for two reasons: 1) to assure that angular measurements of peak breadth would be comparable, and 2) to enable the graphing of mineral percentages against observed peak intensities.

The following standard mixtures were prepared from which standard intensity graphs vs. mineral percent were plotted:

Quartz	*Illite*	*Kaolinite*	*Feldspar*	*14-15A Minerals*
80	10	5	5	0
65	20	10	5	0
55	10	20	5	10
50	30	10	10	0
50	20	5	15	10
40	25	20	10	5
25	40	15	5	15

These mineral ranges were expected to cover the range of the majority of clay-shale samples to be analyzed. Each mineral was X-rayed separately to insure purity. The "illite" used was actually a 2M crystalline, pegmatitic muscovite with essentially no line broadening. The kaolinite used was Ward's Clay Mineral Standard No. 4 from the Oneal Pit, Macon, Georgia. For the feldspar, a perthitic intergrowth of potash and plagioclase feldspar was used. No attempt was made to separate K, Na, and Ca feldspars. For the 14-15A component a Mg-Fe chlorite was mixed with vermiculite (Brinton quarry, West Chester) in a 3:2 ratio. Each standard was X-rayed a minimum of 9 times after thorough mixing. From the resultant patterns, the following reflections were chosen to be measured for each mineral as representing the best combination of least interference, strongest reflection, and shortest 2θ scan:

6.0 – 6.2° 2Θ	:	chlorite vermiculite, montmorillonite (001)
8.8 – 8.9° 2Θ	:	illite (001)
12.2 – 12.5° 2Θ	:	kaolinite (001) after subtraction of 14-15A minerals
20.82° 2Θ	:	quartz (100)
27.4 – 28.1° 2Θ	:	total feldspar (strongest reflections)

All intensities were measured by subtracting background from peak height.

Average intensity data from the standard mixture curves were plotted in two ways. The average observed intensities from the diffractometer traces at constant instrument settings were plotted directly against mineral percent. However, such a plot is subject to variations from preferred orientation, packing density, instrument repeatability, and matrix absorption. A more reliable graph is the total intensity for all 5 components replotted as an intensity ratio calculated to 100% (I calc.) vs. mineral percent. The resultant standard curves using calculated intensities are shown in Figure 4. As expected, these curves are not linear over wide percentage ranges, a result of the type of errors discussed previously. The quartz values determined from the observed and the calculated intensity curves agree quite closely because quartz is not subject to preferred orientation, packing variability, changes in degree of crystallinity, etc. The curves shown in Figure 4 are second derivative

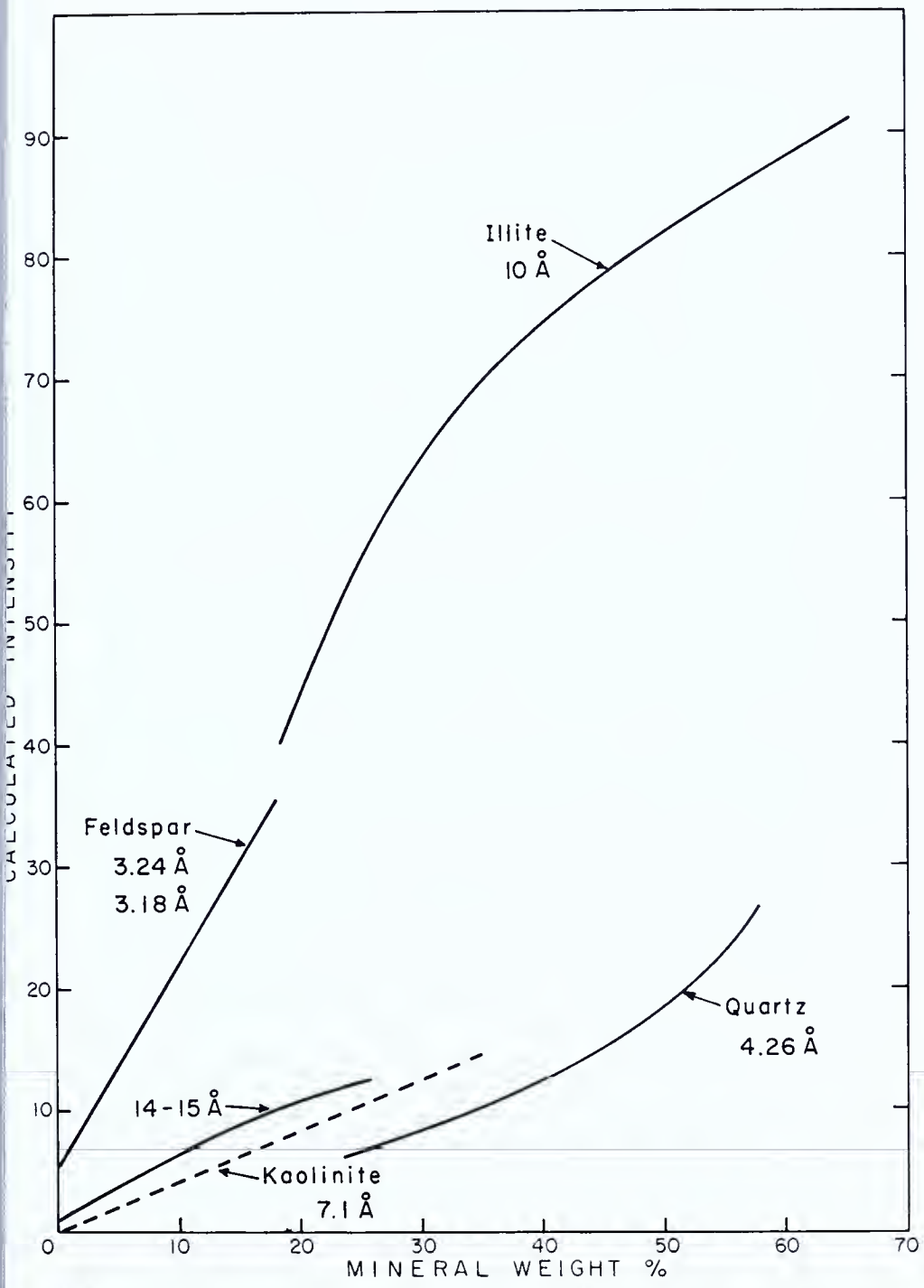


Figure 4. Quantitative mineral standardization curves derived from X-ray reflection intensities.

curves replotted from vectorial adjustment of the scatter of points from the calculated intensity curves (a successive approximation method of producing an average curve) for the standard mixtures and for the cal-

Table 6—*Mineral percent calculation.*

Location No. 59 - 6 - 1		Unit : Friendsville Shale, Conemaugh Fm.					% Impurities: ~ 5%	
Mineral	*2θ*	*I. #1*	*I. #2*	*I. #3*	*Avg.*	*I. - Observed*	*I. - Calc.*	*%*
14 - 15 A	6.2	4.3	3.3	4.3	3.9	3.9	3.2	3 ± 3
Illite	8.9	8.9	8.0	8.3	8.4	94.1	77.3	44 ± 8
Kaolinite + 14 - 15 A	12.4	8.6	6.8	8.0	7.8	Kaol. ~ 3.0	2.4	6 ± 6
Quartz	20.8	16.7	13.9	14.0	14.9	14.9	12.0	38 ± 8
Feldspar	27.5 & 28.0	6.5	6.6	8.0	6.8	6.8	5.6	1 ± 3
Illite Peak Breadth		25.5°	23.5°	19.0°	22.7°			
						Total = 122.7		Total = 93.0%

$$I._{mi}\ (\text{Fig. 3}) = \frac{F_{mi}}{11.2} \times \frac{\text{Avg. I.}}{8.4} = \frac{\text{I. Obs.}}{94.1}$$

Kaolinite I. = 7.8 - (1.2 × 3.9) = 3.0

$$\text{I Calc.} = \frac{100}{122.7} \times \text{Observed I.}$$

Mineral % : from Fig. 4

culated mineral percents from 50 unknown clay-shale samples (for which the standard mixture graphs had been used).

An example of the calculation of mineral percent is illustrated in Table 6. The F_{ml} was determined from the curve in Figure 3. For samples with large percentages of kaolinite, the kaolinite percent was found by subtracting the total percent of all other minerals from 100%. The discrepancy in amount of kaolinite between this method and the graphical method is greatest where vermiculite or montmorillonite (rather than chlorite) comprise the majority of the intensity of the 14-15A reflection and hence contribute least to the 7A combined reflection. An attempt was made to estimate impurities (largely calcite) and where significant, the total intensity of the minerals determined was summed to less than 100%. The average determined mineral content of all unknown samples analyzed is 92%.

Accuracy of Mineral Analysis

The numerous assumptions and approximations upon which X-ray analysis of minerals in polycomponent mixtures rests have been discussed. It is impossible to evaluate the amount of error involved in each. The best estimate of error available is the point scatter of unknown samples replotted on the percentage graphs of the standard mixture curves. For samples in which kaolinite and the 14-15A minerals do not individually exceed 10%, the accuracy range is considered to be as follows (expressed in mineral percent):

Chlorite-Vermiculite-Montmorillonite: ±3
Feldspar: ±3
Quartz: ±6
Mica (Illite): ±7
Kaolinite: ±8

In many cases inaccuracy is the result of quantitatively undetermined minerals (calcite, goethite, etc.). For several samples, the X-ray reflectivity was so weak that peak heights and illite peak widths could not be measured accurately. Others are inaccurate because of high percentages of kaolinite, which, because of the ratio method of calculation, results in errors in the other mineral components.

Comparison of Chemical and Mineral Analyses

A comparison of quantitative wet chemical analysis and quantitative mineral analysis serves as an independent check on the accuracy of the mineral analysis method. Two examples of such a comparison are illustrated in Table 7.

Table 7—*Comparison of chemical composition by wet chemical and mineral analysis methods.*

Sample No. 59-6-1		
Unit: Conemaugh Friendsville Shale		
% Oxide	*Chemical Anal.*	*Mineral Anal. Recalc.*
MgO	1.33	1.0
Al_2O_3	19.85	20.1
SiO_2	55.00	62.3
K_2O	3.40	3.7*
Sample No. 197-3-1		
Unit: Triassic Brunswick Shale		
% Oxide	*Chemical Anal.*	*Mineral Anal. Recalc.*
MgO	1.76	1.3
Al_2O_3	14.50	14.7
SiO_2	62.50	62.0
K_2O	4.10	3.4*

* Assuming 8.5% K_2O in illite.

The two samples illustrated were chosen at random with the exception that they exhibit approximately the same, rather large angular line broadening (about 22 degrees) of the illite (001) reflection. Mineral percent was reduced to oxide percent by assuming stoichiometric compositions for chlorite (as the 14-15A component), feldspar (assuming ½ the total feldspar to be a potash feldspar), quartz, kaolinite, and illite. In the case of the illite, 8.5% K_2O was assumed rather than the stoichiometric 11.9% because most illites with pronounced line broadening are somewhat potassium deficient.

The agreement is remarkably good for all samples. SiO_2 and Al_2O_3 tend to be high by the mineral recalculation procedure. K_2O is variable because of variable potassium deficiency in illite. Twenty samples were compared in this manner; maximum deviation is as follows:

SiO_2—8.5%

Al_2O_3—5.5%

K_2O—2.5%

MgO—1.5%

Most samples are much closer to the chemical analysis than the above maximum error. Oxides other than those listed were not compared because they are not part of the stoichiometric mineral formulas or vary too greatly by virtue of chemical substitution to be computed accurately.

SAMPLE DATA AND TEST RESULTS

INDIVIDUAL SAMPLE DATA

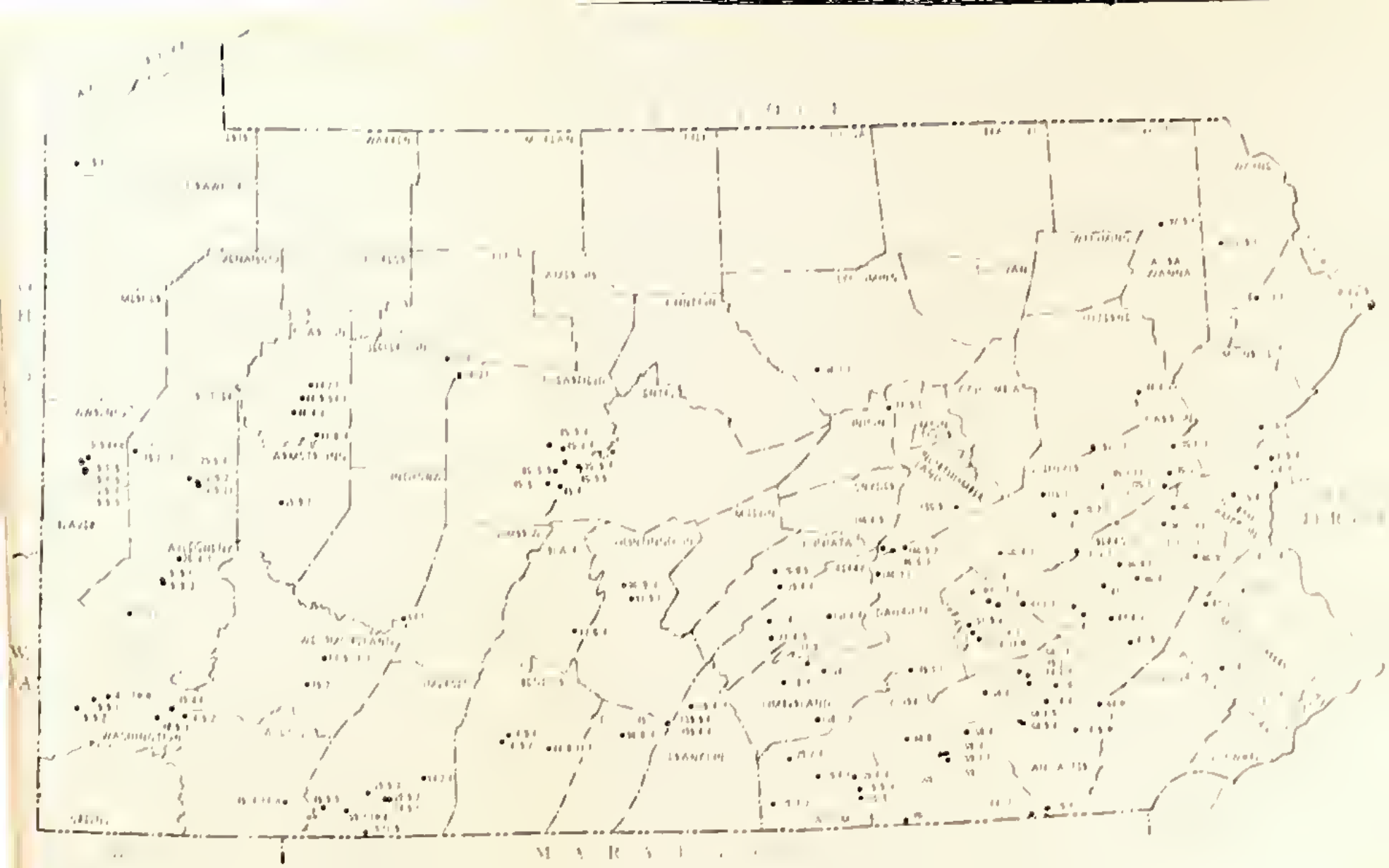
The description data and test results are presented separately for each sample. The order of presentation is by county and sample number. Approximate locations for all samples are shown on Figure 5.

A word of caution: the evaluation remarks are based on test data determined on one or a few samples from each locality. Detailed exploration, including additional sampling and testing, should be carried out to prove any particular locality for commercial development. Likewise, the test results of one sample from a stockpile may not be representative of all the material.

Some of the terms on the data sheets may need clarification and are defined below:

CO_2*: recalculated from CO_3=
CO_2: both CO_3= and C recalculated to CO_2
C-V-Mo: chlorite, vermiculite, and montmorillonite grouped together
L.O.I: CO_2 or CO_2*, H_2O combined, and H_2O at 120° C.
N.A.: not available
ASG: apparent specific gravity
% Abs: percent of absorption
% Shk: percent drying shrinkage

Rotary Kiln Tests—Material Sizes: should be read in inches if fractions, in mesh if whole numbers.



ADAMS COUNTY

Sample Number

129-2-1

Quadrangle: Fairfield 15'; Arendtsville 7½'

Location: Exposure along the northeast side of State Route 234 about 3.7 miles northwest of Arendtsville.

Geologic Unit: Precambrian schist

Description: An exposure of pale-orange and orange-yellow clay which grades down into weathered schist extends for a distance of 500 feet along the road. The clay is the residual product from weathering of the parent sericite schist of Precambrian age. Minor amounts of quartz vein material occur in the clay. The exposure is 12 feet high, the upper two feet of which consists of soil overburden.

Sampled Interval: Channel sample through 10 feet of clay and weathered schist.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	67.50
Al_2O_3	19.00
Fe_2O_3	2.64
FeO	.46
CaO	.04
MgO	.18
K_2O	3.75
Na_2O	.26
TiO_2	.30
L.O.I.	5.85
S	.008
CO_2	.18
comb. H_2O	5.67

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	51	6
Mica	25	6
Kaolinite	9	5
C-V-Mo	1	3
Feldspar	9	4

Other Tests:

pH: 6.3
Workability: fair plasticity, fine grit, short
Water of plasticity %: 25.0
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. buff-red	Soft, crumbly	4.0	20.0	2.45
1900	Lt. buff-red	Soft, crumbly	5.5	19.8	2.47
2000	Lt. buff-red	Fairly hard	5.5	17.7	2.47
2100	Tan-red	Steel hard	6.5	12.4	2.42
2200	Lt. tan gray	Steel hard	9.0	8.5	2.35
2300	Gray tan	Steel hard	11.0	4.0	2.31

Bloating Test: Negative

Potential Uses: Decorative brick and tile if color is acceptable to trade.

Remarks: Tan-red fired color at 2100°F is attractive.

ADAMS COUNTY

Sample Number

129-7-2

Quadrangle: Fairfield 15'; Iron Springs 7½'

Location: Quarry on the north side of the Mt. Hope road about 3 miles west-northwest of Fairfield.

Geologic Unit: Precambrian schist

Description: A band of varicolored sericite schist, about 100 feet wide, occurs at the contact of greenstone and rhyolite and is being quarried for filler material by the Aspers Industrial Company, Aspers, Pennsylvania. The schist is greenish gray, pink, and purple.

Attitude of Schistosity: Strike NE-SW; dips steeply NW
Sampled Interval: Grab sample of broken quarry rock at working face.

Type of Material: sericite schist

Chemical Analysis:

	%
SiO_2	71.00
Al_2O_3	15.30
Fe_2O_3	2.72
FeO	.64
CaO	.16
MgO	1.58
K_2O	4.85
Na_2O	.70
TiO_2	.35
L.O.I.	2.65
S	.002
CO_2	.18
comb. H_2O	2.33
H_2O @ 120°C	.14

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	55	8
Mica	28	8
Kaolinite	5	5
C-V-Mo	3	3
Feldspar	4	3

Remarks: carbonate mineral present

Other Tests:

pH: 7.4
Workability: not plastic, short and crumbly
Water of plasticity %: 16.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff yellow	Soft, crumbly	1.0	17.7	2.46
1900	Buff yellow orange	Soft, crumbly	1.0	15.1	2.44
2000	Buff yellow orange	Fairly hard	2.0	12.9	2.44
2100	Lt. brown	Very hard	6.0	7.4	2.38
2200	Dk. brown	Steel hard	7.5	2.3	2.31
2300	Dk. brown	Steel hard	7.5	2.0	2.12

Bloating Test: Negative

Potential Uses: Inert mineral filler.

ADAMS COUNTY

Sample Number

139-4-1

Quadrangle: Gettysburg 15'; Biglerville 7½'

Location: Exposure along the west side of State Route 394 about 2.5 miles southeast of Biglerville.

Geologic Unit: Heidlersburg Member, Gettysburg Formation, Triassic Age

Description: An exposure of greenish-gray and red interbedded shale and siltstone, about 12 feet in height, extends for a distance of 430 feet along the west side of State Route 394. The rocks are overlain by 2 feet of soil overburden.

Attitude of Bedding: N48E; 19NW

Sampled Interval: 13-foot channel sample

Type of Material: interbedded shale and siltstone

Chemical Analysis:

	%
SiO_2	53.50
Al_2O_3	16.50
Fe_2O_3	4.04
FeO	3.38
CaO	3.32
MgO	2.65
K_2O	4.70
Na_2O	2.90
TiO_2	.68
L.O.I.	8.24
S	.04
CO_2	3.89
comb. H_2O	4.35

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	31	8
Mica	23	6
Kaolinite	1	3
C-V-Mo	15	7
Feldspar	13	6

Remarks: calcite, dolomite, goethite present

Other Tests:

pH: 8.2
Workability: not plastic, short and slightly gritty
Water of plasticity %: 21.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	5.0	18.2	2.55
1900	Buff orange	Soft, crumbly	5.0	17.7	2.54
2000	Buff orange	Fairly hard	5.0	13.1	2.40
2100	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.16	134.6	2.7	No bloating
2000	1.90	118.4	2.8	No bloating
2100	1.05	65.4	5.0	Fair bloating
2200	0.78	48.6	5.9	Good bloating, slightly sticky

Evaluation: This sample is a mixture of weathered and unweathered material; the unweathered material might make good lightweight aggregate.

Potential Uses: Unweathered shale might make good lightweight aggregate. This material could probably be mixed with structural type clays as a fluxing material to lower the vitrification temperature.

ADAMS COUNTY

Sample Number

139-6-3

Quadrangle: Gettysburg 15'; McSherrystown 7½'

Location: Quarry about 1.5 miles southeast of New Oxford and about 0.5 mile south-southeast of the Alwine Brick Company plant in Berlin Junction.

Geologic Unit: New Oxford Formation, Triassic Age

Description: Reddish-brown and green shales, about 25 feet in height, are exposed in a quarry for a distance of more than 1000 feet along the strike of the beds. Two to three feet of soil overlies the shale at the surface. The Alwine Brick Company uses the shale in the manufacture of brick.

Attitude of Bedding: N25E; 27NW

Sampled Interval: Channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	66.70
Al_2O_3	15.70
Fe_2O_3	6.45
FeO	.77
CaO	.33
MgO	.98
K_2O	2.40
Na_2O	1.30
TiO_2	1.06
L.O.I.	4.24
S	.004
CO_2	.11
comb. H_2O	4.13

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	43	6
Mica	42	8
Kaolinite	0	2
C-V-Mo	3	3
Feldspar	4	3

Remarks: C-V-Mo is largely vermiculite (V)

Other Tests:

pH: 5.8
Workability: not plastic, short and gritty
Water of plasticity %: 18.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. red brown	Soft, crumbly	4.0	14.3	2.32
1900	Lt. red brown	Soft, crumbly	4.0	12.9	2.32
2000	Brown red	Fairly hard	4.0	12.8	2.32
2100	Brown	Hard	5.5	8.1	2.34
2200	Dk. brown	Very hard	7.5	5.8	2.36
2300	Dk. brown	Very hard	8.0	4.1	2.38

Bloating Test: Negative

Potential Uses: Brick.

Remarks: Specific gravities are low in comparison with typical brick shales.

ADAMS COUNTY

Sample Number

139-6-4

Quadrangle: Gettysburg 15'; Hampton 7½'

Location: Alwine Brick Company quarry about 2 miles north of New Oxford and about 700 feet southwest of Sevenhundred School.

Geologic Unit: New Oxford Formation, Triassic Age

Description: Weathered red shales are exposed in a quarry which is approximately 10 feet deep and which has been developed for several hundred feet along the strike of the beds. The shales are used by the Alwine Brick Company in the manufacture of brick.

Sampled Interval: Channel sample taken 2 to 10 feet vertically below surface in northeast corner of the quarry

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.30
Al_2O_3	18.45
Fe_2O_3	6.88
FeO	.92
CaO	.47
MgO	1.32
K_2O	2.40
Na_2O	1.75
TiO_2	1.02
L.O.I.	4.41
S	.006
CO_2	.18
comb. H_2O	4.23

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	35	8
Mica	28	6
Kaolinite	8	4
C-V-Mo	10	5
Feldspar	8	4

Other Tests:

pH: 6.0
Workability: not plastic, short and gritty
Water of plasticity %: 19.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. red brown	Soft, crumbly	3.5	11.9	2.36
1900	Lt. red brown	Soft, crumbly	3.5	14.1	2.36
2000	Lt. brown	Fairly hard	5.0	12.2	2.37
2100	Dk. brown red	Hard	6.1	6.1	2.35
2200	Dk. brown	Very hard	9.0	2.3	2.35
2300	Black brown	Steel hard	9.5	1.1	2.31

Bloating Test: Negative

Potential Uses: Brick

Remarks: Specific gravities are low in comparison with typical brick shales.

ADAMS COUNTY

Sample Number

139-9-2

Quadrangle: Gettysburg 15'; McSherrystown 7½'

Location: The Hanover quarry of Bethlehem Steel Company about 2 miles north-northwest of McSherrystown.

Geologic Unit: Kinzers Formation, Cambrian Age

Description: A twelve-foot-high exposure of a residual dark-yellow-orange clay is developed over the Kinzers complex of limestone and dolomite in the quarry. Minor amounts of greenish-gray shale chips occur in the clay. The clay is overlain by 2 feet of soil overburden.

Attitude of Bedding: NE-SW strike; NW dip

Sampled Interval: Channel sample from 2 to 12 feet below surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	55.80
Al_2O_3	22.02
Fe_2O_3	7.48
FeO	.36
CaO	.13
MgO	.87
K_2O	5.00
Na_2O	.34
TiO_2	.97
L.O.I.	7.00
S	.016
CO_2	.48
comb. H_2O	5.43
H_2O @ 120°C	1.09

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	45	8
Mica	36	8
Kaolinite	2	2
C-V-Mo	3	2
Feldspar	5	3

Remarks: carbonate mineral present

Other Tests:

pH: 4.9
Workability: fairly plastic and smooth, slightly gritty
Water of plasticity %: 26.0
% Drying shrinkage: 4.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Orange buff	Soft, crumbly	5.5	20.2	2.60
1900	Orange buff	Soft, crumbly	7.0	24.8	2.62
2000	Dk. orange buff	Very hard	9.0	12.8	2.57
2100	Brown	Steel hard	11.0	5.8	2.50
2200	Dk. brown	Steel hard	12.5	6.6	2.55
2300	Dk. brown	Steel hard	12.5	2.2	2.35

Bloating Test: Negative

Potential Uses: Brick, drain tile, and possibly floor tile.

ALLEGHENY COUNTY

Sample Number

16-9-2

Quadrangle: Sewickley 15'; Emsworth 7½'

Location: East side of McKnight Road about 0.5 mile south of its intersection with McIntyre Road.

Geologic Unit: Ames horizon, Conemaugh Formation, Pennsylvanian Age

Description: Medium-dark-gray, thin-bedded shale and silty shale occur about 50 stratigraphic feet above the Ames limestone and directly underneath the Morgantown sandstone. The beds average between ¼ and ½ inch in thickness. The upper 3 to 4 feet of the sampled section is more silty and is commonly iron-stained.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample taken 0 to 10 feet below the Morgantown sandstone

Type of Material: shale and silty shale

Chemical Analysis:

	%
SiO_2	59.60
Al_2O_3	19.05
Fe_2O_3	3.51
FeO	4.26
CaO	.20
MgO	1.45
K_2O	2.99
Na_2O	.89
TiO_2	.94
L.O.I.	7.08
S	.56
CO_2*	3.17
comb. H_2O	3.91
H_2O @ 120°C	.80

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	29	8
Mica	35	8
Kaolinite	19	8
C-V-Mo	7	4
Feldspar	1	3

Remarks: some montmorillonite (Mo) present and carbonate minerals

Other Tests:

pH: 4.2
Workability: not plastic, short and gritty
Water of plasticity %: 23.8
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	1.0	25.8	2.66
1900	Dk. buff brown	Fairly hard	4.5	21.2	2.57
2000	Brown	Very hard	5.0	17.7	2.59
2100	Dk. brown	Steel hard	7.5	9.6	2.51
2200	Very dk. brown	Steel hard	4.5	2.8	2.20
2300	Very dk. brown	Steel hard	10.0	14.4	1.95

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800				
1900	1.99	124.0	7.6	No bloating
2000	1.59	99.1	9.9	No bloating
2100	1.0	62.3	19.4	Good bloating
2200	0.78	48.6	15.2	Excellent bloating, slightly sticky
2300	0.69	43.0	21.1	Over bloated and very sticky

Evaluation: Good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	47.0
—1/4 + 1/8	28.6
—1/8 + 16	24.4
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	15.0
—3/8 + 1/4	28.4
—1/4 + 8	17.3
— 8 + 16	14.8
—16 + 35	10.6
—35 + 65	6.6
—65	7.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1920	1970
Optimum	1945	1965
Maximum	2040	2120

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	108
Fired	58
Effect of quenching	NA
Processing characteristics	Fair
Material flow	Uniform
Point of release	11:00
Particle shape	Angular, Rounded & Elongated
Pore structure	Medium, Fine
Expansion	Fair
Uniformity of firing	NU
Color	Lt. br. to gray

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.³*	*% Abs.*
—3/4 + 1/2	1.33	82.9	6.8
—1/2 + 1/4	1.44	89.7	7.6
—1/4 + 8 mesh	1.56	97.2	8.3

Screen analysis

Size	*Percent retained*
+3/8	38.2
—3/8 + 1/4	40.1
—1/4 + 8	18.5
— 8 + 16	2.2
—16 + 35	.3
—35 + 65	.2
—65	.5
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.5
Lb/Ft³	93
Compression (PSI)	5589
Color (colorimeter)	44
Cure	Autoclave
% Abs.	5.5

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.52
Lb/Ft³	95
Compression (PSI)	2447
Color (colorimeter)	41
Cure	28 Day Steam
% Abs.	7.1

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.51	Bulk Sp. Gr.	1.58
Lb/Ft^3	94	Lb/Ft^3	98
Compression (PSI)	6162	Compression (PSI)	3438
Color (colorimeter)	43	Color (colorimeter)	32
Cure	Autoclave	Cure	28 Day Steam
% Abs.	5.8	% Abs.	9.5

Potential Uses: Brick and fair lightweight aggregate; possibly floor tile.

Remarks: Bloating tests (quick-firing) indicated that this material would make a good lightweight aggregate, but subsequent rotary kiln tests on a bulk sample of the material indicated it would only make a fair lightweight aggregate.

ALLEGHENY COUNTY

Sample Number

16-9-3

Quadrangle: Sewickley 15'; Emsworth 7½'

Location: East side of McKnight Road, 0.6 mile north of its intersection with Siebert Road.

Geologic Unit: Ames horizon, Conemaugh Formation, Pennsylvanian Age

Description: Medium-gray, calcareous shales, measuring ten feet thick, occur between two limestone units, all of these being parts of the Ames limestone horizon. Bedding is poorly defined in the shales. Concretions up to one foot in diameter occur within one bed. The exposure extends for a distance of 500 feet along the roadway.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 10-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	53.20
Al_2O_3	17.20
Fe_2O_3	2.68
FeO	3.65
CaO	5.30
MgO	2.19
K_2O	3.21
Na_2O	.45
TiO_2	.77
L.O.I.	11.34
S	.045
CO_2*	4.68
comb. H_2O	6.66
H_2O @ 120°C	1.34

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	35	6
Mica	43	8
Kaolinite	3	3
C-V-Mo	2	2
Feldspar	1	3

Remarks: calcite and dolomite present

Other Tests:

pH: 9.3
Workability: fair plasticity, slightly short
Water of plasticity %: 18.7
% Drying shrinkage: 5.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	5.0	14.3	2.59
1900	Dk. buff brown	Hard	5.5	12.2	2.60
2000	Dk. buff brown	Very hard	9.0	10.7	2.58
2100	Brown red	Steel hard	10.0	6.0	2.46
2200	Very dk. brown	Steel hard	10.6	2.2	2.04
2300	Melted				

Bloating Test: Slight expansion.

Potential Uses: Brick, tile, and possibly sintered aggregate.

Remarks: Acid treatment shows the presence of a large amount of calcareous material.

ALLEGHENY COUNTY

Sample Number

17-2-1

Quadrangle: Carnegie 15'; Oakdale 7½'

Location: Exposure east of the northeast portion of the cloverleaf at the Oakdale Exit on the Parkway West Highway and about 200 feet northwest of State Route 60.

Geologic Unit: Conemaugh Formation, Pennsylvanian Age

Description: Interbedded, thin-bedded, pale-green, yellow and yellow-gray shales and siltstones with some red shales occur from 20 to 31 feet stratigraphically below the Pittsburgh limestone. The exposure extends for a distance of 400 feet along the roadway.

Sampled Interval: Channel sample taken from 20 to 31 feet below the Pittsburgh limestone

Type of Material: shales and siltstones

Chemical Analysis:

	%
SiO_2	58.80
Al_2O_3	21.00
Fe_2O_3	7.23
FeO	.99
CaO	.48
MgO	1.11
K_2O	2.48
Na_2O	.42
TiO_2	1.00
L.O.I.	6.45
S	.024
CO_2*	.29
comb. H_2O	6.16
H_2O @ 120°C	1.78

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	41	8
Mica	44	8
Kaolinite	0	2
C-V-Mo	8	4
Feldspar	0	2

Remarks: some montmorillonite (Mo) present

Other Tests:

pH: 5.0
Workability: plastic, smooth, slightly short
Water of plasticity %: 18.4
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	5.0	15.0	2.68
1900	Dk. buff brown	Hard	7.5	11.1	2.66
2000	Dk. buff brown	Very hard	10.0	18.1	2.54
2100	Brown red	Steel hard	10.5	4.8	2.52
2200	Very dk. brown	Steel hard	11.0	2.6	2.51
2300	Melted				

Bloating Test: Slight expansion.

Potential Uses: Brick and floor tile.

ALLEGHENY COUNTY

Sample Number

26-4-1

Quadrangle: New Kensington 15'; Glenshaw 7½'

Location: Exposure on the east side of State Route 80, about 0.6 mile north of the Route 80 overpass to the Pennsylvania Turnpike.

Geologic Unit: Pittsburgh red beds, Conemaugh Formation, Pennsylvanian Age

Description: Pale-red, gray-red, and pale-brown claystone occurs about 15 feet below the base of the Ames limestone. The exposed section of claystone measures 8 stratigraphic feet and extends for a distance of about 250 feet parallel to Route 80.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 8-foot channel sample

Type of Material: claystone

Chemical Analysis:

	%
SiO_2	57.40
Al_2O_3	18.60
Fe_2O_3	5.41
FeO	1.06
CaO	3.93
MgO	1.16
K_2O	2.49
Na_2O	.22
TiO_2	.86
L.O.I.	8.86
S	.024
CO_2*	2.71
comb. H_2O	6.15
H_2O @ 120°C	2.89

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	40	8
Kaolinite	0	2
C-V-Mo	3	3
Feldspar	0	3

Remarks: calcite and dolomite present, quartz and mica probably high

Other Tests:

pH: 9.2
Workability: plastic and smooth, slightly gritty
Water of plasticity %: 22.6
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	5.0	15.3	2.59
1900	Lt. brown	Very hard	10.0	11.6	2.59
2000	Brown	Steel hard	10.5	5.3	2.48
2100	Dk. brown	Steel hard	11.0	3.4	2.40
2200	Very dk. brown	Steel hard	Exp.	4.8	2.13
2300	Very dk. brown	Steel hard	Exp.	1.1	2.14

Bloating Test: Slight expansion.

Potential Uses: Brick and possibly sintered aggregate.

Remarks: Acid treatment shows appreciable calcareous material present.

ARMSTRONG COUNTY

Sample Number

35-9-1

Quadrangle: Kittanning 15'; Kittanning 7½'

Location: West side of Pittsburgh and Shawmut Railroad about 500 feet south of the station in Applewold.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray, plastic clay occurs in two separate zones beneath the Lower Kittanning coal. The uppermost zone which measures 8 stratigraphic feet occurs directly under the coal. It is separated from a lower clay by 23 inches of medium-bedded sandstones and 12 inches of carbonaceous shale. The exposed thickness of the lower clay is 28 inches.

Attitude of Bedding: Gentle dip to southeast

Sampled Interval: 10-foot channel sample from upper and lower clay zones

Type of Material: clay

Chemical Analysis:

	%
SiO_2	70.30
Al_2O_3	17.50
Fe_2O_3	1.17
FeO	.91
CaO	.09
MgO	.37
K_2O	1.27
Na_2O	.39
TiO_2	1.50
L.O.I.	6.45
S	.20
CO_2*	.53
comb. H_2O	5.06
H_2O @ 120°C	.66

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	55	8
Mica	31	6
Kaolinite	11	6
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 3.7
Workability: not plastic, short and gritty
Water of plasticity %: 22.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Med. buff	Soft, crumbly	4.5	21.3	2.50
1900	Buff orange	Soft, crumbly	4.5	21.2	2.53
2000	Buff orange	Soft, crumbly	5.0	18.5	2.53
2100	Brown buff	Soft, crumbly	6.0	17.1	2.51
2200	Lt. brown	Very hard	8.0	15.2	2.51
2300	Lt. brown gray	Steel hard	10.0	15.8	2.60

Bloating Test: Negative

Potential Uses: None unless mixed with a lower firing plastic clay.

BEDFORD COUNTY

Sample Number

78-9-1

Quadrangle: Bedford 15'

Location: Exposure along the north side of the Pennsylvania Turnpike about 0.9 mile west of the town of Wolfsburg and about 3 miles northwest of Bedford.

Geologic Unit: Wills Creek Formation, Silurian Age

Description: Interbedded shales and siltstones extend for a distance of about 600 feet along the turnpike. The dominant colors are light olive gray and greenish gray but purple and tan beds also occur within the exposure. The beds range in thickness from less than one inch up to four inches. The height of the exposure is about 20 feet and the overburden measures from one to two feet.

Attitude of Bedding: NE-SW strike; Moderate dip to NW

Sampled Interval: Grab sample taken from entire exposure

Type of Material: shales and siltstones

Chemical Analysis:

	%
SiO_2	41.30
Al_2O_3	9.70
Fe_2O_3	1.40
FeO	1.98
CaO	17.30
MgO	3.26
K_2O	3.53
Na_2O	.20
TiO_2	.43
L.O.I.	20.84
S	.08
CO_2*	18.15
comb. H_2O	2.04
H_2O @ 120°C	.57

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	32	8
Mica	53	10
Kaolinite	0	2
C-V-Mo	3	2
Feldspar	0	1

Remarks: calcite and other carbonates

Other Tests:

pH: 9.15
Workability: not very plastic, slightly gritty, very short
Water of plasticity %: 18.0
% Drying shrinkage: 0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. buff pink	Soft, crumbly	0.0	30.1	2.86
1900	Lt. buff pink	Soft, crumbly	0.0	31.2	2.87
2000	Lt. buff pink	Soft, crumbly	0.0	30.9	2.87
2100	Lt. buff	Soft, crumbly	0.0	30.9	2.86
2200	Lt. mottled brown	Very hard	Starting to slag	21.3	2.82

Bloating Test: Negative

Potential Uses: None.

BEDFORD COUNTY

Sample Number

78-9-2

Quadrangle: Bedford 15'

Location: Exposure along the northwest side of the Pennsylvania Turnpike at mileage marker 141.7 about 4 miles west-northwest of Bedford.

Geologic Unit: Marcellus Formation, Hamilton Group, Devonian Age

Description: Medium-gray, fissile, carbonaceous shales, with some silty beds up to several inches thick, occur in the lower part of the Marcellus Formation in this exposure. Yellow and brown iron staining is common along fractures in the rock. The shale breaks down on weathering into small, platy fragments which are usually pale orange and gray yellow in color. The soil overburden is thin, measuring less than 6 inches.

Attitude of Bedding: NE-SW strike; dip about 55 degrees to SE

Sampled Interval: Grab sample taken from entire exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	59.90
Al_2O_3	19.05
Fe_2O_3	6.01
FeO	1.04
CaO	.33
MgO	.85
K_2O	3.95
Na_2O	.95
TiO_2	.97
L.O.I.	6.92
S	.20
CO_2	3.63
comb. H_2O	2.81
H_2O @ 120°C	.48

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	46	8
Mica	39	8
Kaolinite	0	3
C-V-Mo	4	3
Feldspar	2	2

Other Tests:

pH: 6.7
Workability: slightly plastic, short
Water of plasticity %: 22.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	2.0	21.6	2.70
1900	Lt. brown	Soft, crumbly	2.0	18.9	2.69
2000	Lt. brown	Fairly hard	2.5	15.7	2.70
2100	Brown	Very hard	5.0	12.3	2.64
2200	Dk. brown	Steel hard	7.0	6.7	2.48
2300	Dk. brown gray	Steel hard	Exp.	6.8	2.72

Bloating Test: Negative

Potential Uses: Possibly brick.

BEDFORD COUNTY

Sample Number

88-8-1A

Quadrangle: Everett 15'

Location: Exposure along the south side of the Pennsylvania Turnpike about 0.5 mile south of Everett.

Geologic Unit: Gander Run Member, Mahantango Formation, Hamilton Group, Devonian Age

Description: Thin-bedded, medium- and medium-dark-gray shales and silty shales occur in the western part of the exposure for a distance of about 125 feet. The thickest beds measure 3 to 4 inches. They are the more siliceous silty shales and are difficult to break. By comparison, the shale beds break easily to form pencil-shaped fragments. Some dark-yellow-orange staining occurs along fractures. The height of the exposure is about 30-35 feet.

Attitude of Bedding: NE-SW; 41 to 48 degree dip to SE

Sampled Interval: Grab sample from Gander Run Member

Type of Material: shale

Chemical Analysis:

	%
SiO_2	66.80
Al_2O_3	15.50
Fe_2O_3	2.56
FeO	3.60
CaO	.75
MgO	.64
K_2O	3.15
Na_2O	1.45
TiO_2	.98
L.O.I.	4.56
S	.31
CO_2	2.05
comb. H_2O	2.35
H_2O @ 120°C	.16

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	44	8
Mica	35	6
Kaolinite	5	4
C-V-Mo	3	3
Feldspar	2	2

Remarks: carbonate minerals present

Other Tests:

pH: 6.7
Workability: not plastic, very gritty and short, hardens on standing
Water of plasticity %: 19.0
% Drying shrinkage: 0.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	0.0	16.0	2.57
1900	Brown	Soft, crumbly	0.0	16.8	2.55
2000	Med. brown	Fairly hard	0.5	12.0	2.50
2100	Dk. brown	Steel hard	1.0	10.4	2.48
2200	Dk. brown	Steel hard	1.0	5.2	2.24
2300	Expanding and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.15	133.9	4.5	No bloating
1900	1.78	110.9	7.4	No bloating
2000	1.48	92.2	8.1	Slight expansion
2100	1.21	75.4	10.0	Excellent bloating
2200	0.99	61.7	9.9	Excellent bloating

Evaluation: Fair lightweight aggregate. The densities are a little high, but the material expands uniformly, has excellent strength, and low absorption.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	63.8
—1/4 + 1/8	24.3
—1/8 + 16	11.9
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	23.9
—3/8 + 1/4	41.4
—1/4 + 8	15.8
— 8 + 16	7.8
—16 + 35	5.1
—35 + 65	2.7
—65	3.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1980	2030
Optimum	1980	1990
Maximum	2010	2090

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	99
Fired	52
Effect of quenching	NA
Processing characteristics	Good
Material flow	Uniform
Point of release	10:00
Particle shape	Angular
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to dk. br.

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.33	82.9	14.1
—1/2 + 1/4	1.39	86.6	11.2
—1/4 + 8 mesh	1.47	91.6	10.8

Screen analysis

Size	*Percent retained*
+3/8	47.6
—3/8 + 1/4	42.8
—1/4 + 8	7.9
— 8 + 16	.7
—16 + 35	.3
—35 + 65	.2
—65	.5
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft^3	92
Compression (PSI)	6064
Color (colorimeter)	34
Cure	Autoclave
% Abs.	6.4

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft^3	92
Compression (PSI)	6064
Color (colorimeter)	34
Cure	28 Day Steam
% Abs.	6.4

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.58	Bulk Sp. Gr.	1.51
Lb/Ft^3	99	Lb/Ft^3	94
Compression (PSI)	5121	Compression (PSI)	6194
Color (colorimeter)	43	Color (colorimeter)	47
Cure	Autoclave	Cure	28 Day Steam
% Abs.	11.6	% Abs.	5.9

Potential Uses: Good lightweight aggregate; possibly brick and tile if colors are acceptable to the trade.

Remarks: Bloating tests (quick-firing) indicated a fair lightweight aggregate material, but subsequent rotary kiln tests on a bulk sample indicated it would make a good lightweight aggregate.

BEDFORD COUNTY

Sample Number

88-8-1B

Quadrangle: Everett 15'

Location: Exposure along the south side of the Pennsylvania Turnpike at turnpike mileage marker 154.8 about 0.5 mile south of Everett.

Geologic Unit: Frame Member, Mahantango Formation, Hamilton Group, Devonian Age

Description: Dark-gray, fossiliferous, interbedded shales and siltstones of the Frame Member of the Mahantango Formation are exposed for a distance of 125 feet along the Turnpike. The height of the exposure is about 35 feet.

Attitude of Bedding: NE-SW strike; 48 degree dip to SE

Sampled Interval: Grab sample taken starting at turnpike mileage marker 154.8 and going west for a distance of 125 feet.

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	63.62
Al_2O_3	17.00
Fe_2O_3	2.30
FeO	4.48
CaO	.39
MgO	1.33
K_2O	3.80
Na_2O	1.26
TiO_2	.98
L.O.I.	4.82
S	.31
CO_2	1.68
comb. H_2O	2.84
H_2O @ 120°C	.30

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	45	8
Mica	29	6
Kaolinite	16	8
C-V-Mo	2	2
Feldspar	2	2

Other Tests:

pH: 7.15
Workability: not plastic, short, gritty, hardens on standing
Water of plasticity %: 16.0
% Drying shrinkage: 0.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	0.0	13.8	2.57
1900	Brown	Soft, crumbly	0.0	14.0	2.55
2000	Med. brown	Fairly hard	3.5	9.6	2.54
2100	Dk. brown	Steel hard	3.5	8.1	2.43
2200	Dk. brown	Steel hard	Exp.	11.8	2.21
2300	Expanding and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.89	117.7	8.7	No bloating
1900	1.65	102.8	8.4	No bloating
2000	1.30	81.0	9.6	Slight bloating
2100	0.97	60.4	10.0	Excellent bloating
2200	0.87	54.2	10.4	Slightly overbloated, slightly sticky

Evaluation: Good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular & Elongated
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	67.4
—1/4 + 1/8	21.2
—1/8 + 16	11.4
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	26.1
—3/8 + 1/4	42.5
—1/4 + 1/8	13.4
— 8 + 16	7.2
—16 + 35	4.8
—35 + 65	2.4
—65	3.6
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1980	2030
Optimum	1985	2000
Maximum	2000	2080

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	108
Fired	50
Effect of quenching	NA
Processing characteristics	Good
Material flow	Uniform
Point of release	11:00
Particle shape	Angular & Rounded
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to gray

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.33	82.9	10.1
—1/2 + 1/4	1.38	86.0	9.6
—1/4 + 8 mesh	1.57	97.8	9.4

Screen analysis

Size	*Percent retained*
+3/8	48.8
—3/8 + 1/4	37.9
—1/4 + 8	10.3
— 8 + 16	1.4
—16 + 35	.3
—35 + 65	.5
—65	.8
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft^3	92
Compression (PSI)	6629
Color (colorimeter)	38
Cure	Autoclave
% Abs.	7.8

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.56
Lb/Ft^3	97
Compression (PSI)	3779
Color (colorimeter)	41
Cure	28 Day Steam
% Abs.	10.5

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.53	Bulk Sp. Gr.	1.67
Lb/Ft^3	95	Lb/Ft^3	104
Compression (PSI)	6475	Compression (PSI)	3828
Color (colorimeter)	35	Color (colorimeter)	42
Cure	Autoclave	Cure	28 Day Steam
% Abs.	7.8	% Abs.	17.4

Potential Uses: Good lightweight aggregate; possibly brick, tile, and floor tile.

BEDFORD COUNTY

Sample Number

88-8-1C

Quadrangle: Everett 15'

Location: Exposure along the south side of the Pennsylvania Turnpike near turnpike mileage marker 154.8 and about 0.5 mile south of Everett.

Geologic Unit: Upper member, Mahantango Formation, Hamilton Group, Devonian Age

Description: Interbedded medium- to medium-dark-gray shales and siltstones representing the upper part of the Mahantango Formation extend for a distance of 350 feet along the Turnpike east of the mileage marker 154.8. The rock is generally hard and difficult to break. The shapes of fragments are usually tabular or irregular but some of the shale beds break into pencil-like fragments. The height of the exposure is about 30 to 35 feet.

Attitude of Bedding: NE-SW strike; dips about 48 degrees to the SE

Sampled Interval: Grab sample taken starting at turnpike mileage marker 154.8 and going east for a distance of about 350 feet along turnpike

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	68.32
Al_2O_3	14.20
Fe_2O_3	3.98
FeO	2.40
CaO	.57
MgO	1.08
K_2O	3.00
Na_2O	.90
TiO_2	.96
L.O.I.	4.53
S	.06
CO_2	.88
comb. H_2O	3.61
H_2O @ 120°C	.04

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	53	8
Mica	29	6
Kaolinite	7	6
C-V-Mo	3	3
Feldspar	3	2

Remarks: talc?

Other Tests:

pH: 6.0
Workability: not plastic, short, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	1.0	14.3	2.55
1900	Brown	Soft, crumbly	1.0	17.3	2.53
2000	Med. brown	Hard	2.0	12.9	2.52
2100	Dk. brown	Very hard	2.5	12.6	2.50
2200	Very dk. brown	Steel hard	4.5	9.1	2.44
2300	Gray black	Steel hard	4.5	7.3	2.28

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair Particle size —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.09	130.2	5.6	No bloating
2000	1.90	118.4	8.0	No bloating
2100	1.86	115.8	6.1	No bloating
2200	1.24	77.3	6.5	Good expansion

Evaluation: The fired weights are heavy, bloating temperatures high, and the bloating range is short. The material would probably make an acceptable lightweight aggregate using the sintering process.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Fair
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	59.9
—1/4 + 1/8	24.4
—1/8 + 16	15.7
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	23.0
—3/8 + 1/4	37.3
—1/4 + 8	15.2
— 8 + 16	9.8
—16 + 35	6.3
—35 + 65	3.3
—65	5.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1970	2020
Optimum	1985	1990
Maximum	2000	2080

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	109
Fired	74
Effect of quenching	NA
Processing characteristics	Fair
Material flow	Uniform
Point of release	1:00
Particle shape	Angular
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to dk. br.

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.³*	*% Abs.*
—3/4 + 1/2	1.89	117.7	13.9
—1/2 + 1/4	1.90	118.4	18.7
—1/4 + 8 mesh	1.74	108.4	11.2

Screen analysis

Size	*Percent retained*
+3/8	48.5
—3/8 + 1/4	37.7
—1/4 + 8	11.8
— 8 + 16	1.5
—16 + 35	.2
—35 + 65	.1
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.90
Lb/Ft³	118
Compression (PSI)	7305
Color (colorimeter)	47
Cure	Autoclave
% Abs.	8.7

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.75
Lb/Ft³	109
Compression (PSI)	3256
Color (colorimeter)	43
Cure	28 Day Steam
% Abs.	8.7

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.92	Bulk Sp. Gr.	1.78
Lb/Ft^3	120	Lb/Ft^3	111
Compression (PSI)	7962	Compression (PSI)	2991
Color (colorimeter)	34	Color (colorimeter)	39
Cure	Autoclave	Cure	28 Day Steam
% Abs.	7.0	% Abs.	10.0

Potential Uses: Fair lightweight aggregate; possibly brick, tile and floor tile.

Remarks: Bloating tests (quick-firing) indicated this material would probably make an acceptable lightweight aggregate using the sintering process. Subsequent tests on a bulk sample of the material indicated it would make a fair lightweight aggregate by the rotary kiln process.

BERKS COUNTY

Sample Number

167-2-4

Quadrangle: Lebanon 15'; Bethel 7½'

Location: Outcrop along south bank of Swatara Creek about one mile west-southwest of Frystown

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Thin-bedded, grayish-red shale outcrops on a 15- to 20-foot high bank along the south side of Swatara Creek. The upper half of the bank is covered by soil overburden.

Attitude of Bedding: N45E; 30S

Sampled Interval: 9-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.60
Al_2O_3	16.40
Fe_2O_3	6.83
FeO	.80
CaO	.21
MgO	1.94
K_2O	5.05
Na_2O	1.58
TiO_2	.83
L.O.I.	4.75
S	.012
CO_2	.48
comb. H_2O	3.92
H_2O @ 120°C	.35

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	43	8
Mica	36	8
Kaolinite	0	2
C-V-Mo	6	3
Feldspar	3	2

Remarks: carbonate minerals present

Other Tests:

pH: 6.5
Workability: not plastic, very short and mealy
Water of plasticity %: 19.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	1.5	12.2	2.63
1900	Lt. brown	Hard	1.5	8.8	2.62
2000	Brown	Very hard	4.0	5.9	2.59
2100	Dk. brown	Steel hard	Exp.	2.5	2.32
2200	Very dk. brown	Steel hard	Exp. and melting		1.75
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: About ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.77	110.3	2.8	No bloating
2000	1.71	106.5	3.1	No bloating
2100	1.41	87.9	5.5	Slight bloating
2200	1.33	82.9	4.0	Slight bloating

Evaluation: Material may be too weathered for good bloating.

Potential Uses: Possibly brick.

BERKS COUNTY

Sample Number

177-2-1

Quadrangle: Wernersville 15'; Bernville 7½'

Location: Exposure along the east side of State Route 183 at the southern limit of the Borough of Bernville

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Olive-gray, dark-gray, and some red shales of the Martinsburg Formation are exposed at this location. The shales commonly weather to a pale-yellow-brown color. The exposure is about 20 feet high and extends for a distance of about 500 feet along the roadcut. Cleavage is pronounced in the shales and, in the southern part of the exposure, intersecting cleavages have resulted in weathered rock breaking into pencil-shaped fragments.

Attitude of Bedding: Bedding is not discernible

Sampled Interval: Grab sample taken at 5-foot intervals along the entire extent of 500 feet

Type of Material: shale

Chemical Analysis:

	%
SiO_2	68.00
Al_2O_3	12.80
Fe_2O_3	4.41
FeO	2.38
CaO	.25
MgO	2.38
K_2O	2.70
Na_2O	.98
TiO_2	.65
L.O.I.	5.38
S	.020
CO_2	.59
comb. H_2O	4.79

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	47	10
Mica	34	10
Kaolinite	1	4
C-V-Mo	8	5
Feldspar	2	3

Other Tests:

pH: 7.0
Workability: fairly plastic and smooth, fine grit
Water of plasticity %: 23.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	16.8	2.71
1900	Dk. buff brown	Soft, crumbly	5.0	14.4	2.67
2000	Dk. brown	Hard	7.5	9.1	2.60
2100	Very dk. brown	Very hard	7.5	5.4	2.49
2200	Dk. brown	Steel had	Exp.		
2300	Melted and expanded		Exp.		

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1900	2.38	148.2	4.1	No bloating
2000	1.69	105.3	4.5	Slight expansion
2100	1.39	86.6	4.1	Fair expansion
2200	1.35	84.1	3.1	Fair expansion, slightly sticky

Evaluation: Unweathered material has possibilities for lightweight aggregate.

Potential Uses: Possibly brick, floor tile, and lightweight aggregate.

BERKS COUNTY

Sample Number

177-6-2

Quadrangle: Wernersville 15'; Bernville 7½'

Location: Outcrop on the south side of State Route 183 immediately south of Mt. Pleasant

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Thin-bedded, varicolored shales of the Martinsburg Formation are exposed for a distance of 900 feet along the roadcut. The predominant colors of the shales are light olive gray and green gray but some beds are purple, red or tan. The exposure is over 20 feet high and has soil overburden which is generally less than one foot thick at the surface.

Attitude of Cleavage: N70E; 80SE; Bedding is not discernible

Sampled Interval: Composite taken every 25 feet along the 900-foot extent of the exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	58.70
Al_2O_3	19.70
Fe_2O_3	6.64
FeO	2.76
CaO	.11
MgO	1.22
K_2O	3.57
Na_2O	1.15
TiO_2	.95
L.O.I.	5.12
S	.006
CO_2	.66
comb. H_2O	4.46

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	27	6
Mica	50	10
Kaolinite	9	7
C-V-Mo	5	3
Feldspar	1	3

Remarks: quartz may be too high

Other Tests:

pH: 7.1
Workability: not plastic, short
Water of plasticity %: 16.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	2.5	15.8	2.77
1900	Dk. buff brown	Soft, crumbly	3.5	13.2	2.73
2000	Dk. brown	Hard	5.0	10.0	2.70
2100	Dk. brown	Very hard	6.0	8.6	2.69
2200	Very dk. brown	Steel hard	7.0	6.0	2.62
2300	Expanded and melted		Exp.		

Bloating Test: Slight.

Potential Uses: Possibly brick, floor tile and sintered aggregate.

BERKS COUNTY

Sample Number

186-8-2

Quadrangle: Hamburg 15'; Hamburg 7½'

Location: Outcrop is located about 0.5 mile south of Lenhartsville on the west side of the medium-duty road which trends parallel to Maiden Creek and connects Lenhartsville and Dreibelbis.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The outcrop consists predominantly of thin-bedded, olive-gray to green-gray shales which weather to pale-yellow-brown, platy fragments. Interbedded with these shales are some sandy and silty beds up to one foot thick which make up between 5 and 10 percent of the exposed section. The outcrop ranges from 15 to 20 feet in height and extends for a distance of about 180 feet along the roadway. Several feet of overburden overlie the exposed rock.

Attitude of Bedding: N70E; 65S (average)

Sampled Interval: Channel sample through 35 stratigraphic feet at the southernmost part of the exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	70.80
Al_2O_3	12.20
Fe_2O_3	3.26
FeO	3.99
CaO	.23
MgO	1.22
K_2O	2.06
Na_2O	1.76
TiO_2	.76
L.O.I.	3.64
S	.016
CO_2	.40
comb. H_2O	3.24

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	48	10
Mica	25	10
Kaolinite	14	8
C-V-Mo	1	3
Feldspar	8	5

Other Tests:

pH: 7.40
Workability: not plastic, short
Water of plasticity %: 19.0
% Drying shrinkage: 5.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	17.2	2.69
1900	Lt. brown	Soft, crumbly	5.5	14.3	2.68
2000	Brown	Very hard	6.0	9.2	2.61
2100	Dk. brown	Steel hard	7.5	6.3	2.52
2200	Dk. brown	Steel hard	Exp.		
2300	Melted and expanded				

Bloating Test: Slight.

Potential Uses: Brick and sintered aggregate.

BERKS COUNTY

Sample Number

186-9-1

Quadrangle: Hamburg 15'; Kutztown 7½'

Location: Outcrop about 2 miles west of Kutztown on the northeast side of the medium-duty macadam road which trends northwest and west between U. S. Route 422 and Moselem Church.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The outcrop consists of medium-dark-gray shale which weathers to pale-yellow-brown, platy fragments. The outcrop reaches a height of about 20 feet and extends along the roadway for a distance of about 300 feet. The shale is overlain by about one foot of soil overburden.

Attitude of Cleavage: N75E; 32N

Sampled Interval: Channel sample from 1 to 20 feet vertically below surface

Type of Material: shale

Chemical Analysis:

	%
SiO_2	65.00
Al_2O_3	15.00
Fe_2O_3	4.80
FeO	2.52
CaO	.24
MgO	2.03
K_2O	3.25
Na_2O	1.10
TiO_2	.77
L.O.I.	5.21
S	.018
CO_2	1.14
comb. H_2O	3.71
H_2O @ 120°C	.36

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	48	8
Mica	32	8
Kaolinite	3	3
C-V-Mo	7	4
Feldspar	2	2

Remarks: carbonate minerals present

Other Tests:

pH: 7.8
Workability: fair plasticity, short
Water of plasticity %: 23.0
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Med. buff	Soft, crumbly	5.0	20.3	2.72
1900	Med. buff	Soft, crumbly	5.0	17.6	2.68
2000	Red buff	Very hard	7.5	10.0	2.60
2100	Dk. brown	Steel hard	11.0	4.7	2.52
2200	Gray black	Steel hard	Exp.		
2300	Melted and expanded				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.84	114.6	5.3	No bloating
2000	1.12	69.8	5.3	Fair expansion
2100	1.08	67.3	5.2	Good bloating
2200	0.75	46.7	5.1	Good bloating, sticky

Evaluation: Fair lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Poor
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	52.3
—1/4 + 1/8	30.3
—1/8 + 16	17.4
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	33.9
—3/8 + 1/4	28.6
—1/4 + 8	16.6
— 8 + 16	9.4
—16 + 35	5.3
—35 + 65	2.6
—65	3.6
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1960	2010
Optimum	1960	1970
Maximum	1980	2060

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	92
Fired	53
Effect of quenching	NA
Processing characteristics	Good
Material flow	Uniform
Point of release	10:00
Particle shape	Angular & Platy
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.85	115.3	18.1
—1/2 + 1/4	1.55	96.6	21.6
—1/4 + 8 mesh	1.48	92.2	10.5

Screen analysis

Size	*Percent retained*
+3/8	18.2
—3/8 + 1/4	45.1
—1/4 + 8	28.0
— 8 + 16	6.7
—16 + 35	1.2
—35 + 65	.4
—65	.4
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.74
Lb/Ft^3	108
Compression (PSI)	4398
Color (colorimeter)	41
Cure	Autoclave
% Abs.	4.3

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.49
Lb/Ft^3	93
Compression (PSI)	1827
Color (colorimeter)	41
Cure	28 Day Steam
% Abs.	6.0

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.81	Bulk Sp. Gr.	1.71
Lb/Ft^3	113	Lb/Ft^3	106
Compression (PSI)	5032	Compression (PSI)	2447
Color (colorimeter)	54	Color (colorimeter)	39
Cure	Autoclave	Cure	28 Day Steam
% Abs.	6.6	% Abs.	9.2

Potential Uses: Brick and good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated the material would make a fair lightweight aggregate, but subsequent rotary kiln tests on a bulk sample indicated it would make a good lightweight aggregate.

BERKS COUNTY

Sample Number

187-1-2

Quadrangle: Reading 15'; Temple 7½'

Location: Glen-Gery Shale Brick Corporation quarry north-northeast of its Shoemakersville plant.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The rock consists of yellow-gray shale beds which in general range from 2 to 6 inches in thickness. Interbedded with these shales are a few siltier beds. The shales weather to various shades of yellow and brown. The quarry workings are extensive, measuring more than 500 feet by 1000 feet in plan and averaging over 20 feet in height.

Attitude of Bedding: None taken

Sampled Interval: Grab sample from broken rock at the working face

Type of Material: clay

Chemical Analysis:

	%
SiO_2	60.90
Al_2O_3	17.50
Fe_2O_3	5.66
FeO	2.44
CaO	.14
MgO	1.46
K_2O	3.60
Na_2O	.90
TiO_2	1.01
L.O.I.	6.33
S	.01
CO_2	.66
comb. H_2O	4.95
H_2O @ 120°C	.72

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	43	8
Mica	33	10
Kaolinite	1	3
C-V-Mo	11	8
Feldspar	3	3

Other Tests:

pH: 7.40
Workability: fairly plastic, short and fine grit
Water of plasticity %: 23.0
% Drying shrinkage: 3.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	3.0	21.1	2.68
1900	Dk. buff brown	Soft, crumbly	4.0	18.8	2.69
2000	Lt. brown	Hard	7.5	13.1	2.62
2100	Dk. brown	Very hard	11.0	6.4	2.55
2200	Gray black	Steel hard	12.5	2.4	2.44
2300	Melted and expanded				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.18	135.8	7.4	No bloating
2000	2.30	143.2	3.7	No bloating
2100	2.19	136.4	2.8	No bloating
2200	1.32	82.2	2.1	Good expansion

Evaluation: Fair lightweight aggregate.

Potential Uses: Brick and fair lightweight aggregate.

BERKS COUNTY

Sample Number

187-4-3

Quadrangle: Reading 15'; Temple 7½'

Location: Temporary exposure in an excavation for pipe on the west edge of U. S. Highway 122, about 2.5 miles south of the intersection between that highway and State Route 383.

Geologic Unit: Conococheague Group, Cambrian Age

Description: Brown to yellow-brown clay, locally mottled, was exposed in a trench that was excavated for the installation of pipe. The depth of the trench measured seven feet. The clay is probably a residual weathered product of the underlying carbonate rocks.

Attitude of Bedding: None exposed

Sampled Interval: Channel sample from 0 to 7 feet below surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	64.90
Al_2O_3	15.55
Fe_2O_3	7.17
FeO	.32
CaO	.16
MgO	.92
K_2O	3.50
Na_2O	.50
TiO_2	.84
L.O.I.	6.10
S	.016
CO_2	1.43
comb. H_2O	3.71
H_2O @ 120°C	.96

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	51	10
Mica	30	8
Kaolinite	1	2
C-V-Mo	1	2
Feldspar	6	4

Other Tests:

pH: 7.10
Workability: plastic, smooth, fine grit
Water of plasticity %: 35.0
% Drying shrinkage: 5.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown buff	Soft, crumbly	7.0	21.1	2.75
1900	Brown buff	Soft, crumbly	8.0	17.7	2.73
2000	Dk. brown	Hard	11.0	12.9	2.69
2100	Dk. brown	Very hard	11.0	9.8	2.67
2200	Very dk. brown	Steel hard	12.5	6.9	2.60
2300	Gray black	Steel hard	14.0	5.2	2.53

Bloating Test: Negative

Potential Uses: Brick and possibly pigmenting clay.

BERKS COUNTY

Sample Number

187-8-1

Quadrangle: Reading 15'; Birdsboro 7½'

Location: Exposure on the northeast side of U. S. Highway 422 about 2 miles northwest of Baumstown.

Geologic Unit: Brunswick Formation, Triassic Age

Description: Dark-reddish-brown, thin-bedded shales and clays are exposed in a gully which cuts through about 12 feet of stratigraphic section in a distance of about 300 feet.

Attitude of Bedding: N70W; 20N (average)

Sampled Interval: 12-foot channel sample

Type of Material: clay and shale

Chemical Analysis:

	%
SiO_2	64.20
Al_2O_3	15.90
Fe_2O_3	6.21
FeO	.24
CaO	.26
MgO	1.27
K_2O	3.15
Na_2O	1.25
TiO_2	.94
L.O.I.	6.55
S	.012
CO_2	.18
comb. H_2O	4.76
H_2O @ 120°C	1.61

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	43	8
Mica	36	8
Kaolinite	0	2
C-V-Mo	5	4
Feldspar	8	5

Remarks: C-V-Mo mostly vermiculite

Other Tests:

pH: 5.68
Workability: plastic and smooth working
Water of plasticity %: 29.0
% Drying shrinkage: 5.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Med. brown	Soft, crumbly	9.5	21.6	2.64
1900	Med. brown	Soft, crumbly	9.5	17.5	2.62
2000	Dk. brown	Hard	12.5	7.5	2.55
2100	Dk. brown	Very hard	16.0	4.8	2.51
2200	Very dk. brown	Steel hard	16.0	3.6	2.38
2300	Gray black	Steel hard	Exp.		

Bloating Test: Negative

Potential Uses: Brick and possibly pigmenting clay.

BLAIR COUNTY

Sample Number

87-6-1

Quadrangle: Hollidaysburg 15'

Location: Quarry owned by the Woodbury Clay Company about 1 mile southwest of Mines Station on the Springfield Branch of the Pennsylvania Railroad.

Geologic Unit: Gatesburg Formation, Cambrian Age

Description: Extensive quarry operations in the past have resulted in a series of pits and quarries, the largest of which extends for thousands of feet and is more than 100 feet deep. White plastic clay occurs in irregular pockets in a yellow-brown soil and is reported to be of at least three different grades. The operation is now inactive and exposures of the clay are very limited. The sample was collected in the southeasternmost pit where a small pocket of clay, measuring less than 20 feet in its longest dimension, was exposed.

Sampled Interval: Channel sample through the short dimension (4-5 feet) of the pocket of clay

Type of Material: clay

Chemical Analysis:

	%
SiO_2	66.60
Al_2O_3	22.85
Fe_2O_3	.13
FeO	.61
CaO	.04
MgO	.26
K_2O	.70
Na_2O	.07
TiO_2	1.03
L.O.I.	7.68
S	.032
CO_2*	.29
comb. H_2O	7.23
H_2O @ 120°C	.13

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	10
Mica	17	6
Kaolinite	41	12
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 5.8
Workability: very plastic, smooth, and fine grit (unwashed sample); plastic, smooth, and slightly fatty (washed sample)
Water of plasticity %: 32.0 (unwashed sample); 27.0 (washed sample)
% Drying shrinkage: 4.5
Dry strength: average

Slow-Firing Tests (unwashed sample):

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. ivory	Soft, crumbly	5.0	23.6	2.63
1900	Off white	Soft, crumbly	5.0	24.0	2.64
2000	Off white	Soft, crumbly	5.0	23.9	2.64
2100	Off white	Soft, crumbly	10.0	22.0	2.63
2200	Pale ivory	Very hard	10.0	21.9	2.63
2300	Ivory	Steel hard	11.0	12.3	2.65

Bloating Test: Negative

Pyrometric cone equivalent: 31-32. **Cone color:** White.

Slow-Firing Tests (washed sample):

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Faint tan off white	Soft, crumbly	5.0	28.6	2.64
1900					
2000	Off white	Soft, crumbly	5.5	25.7	2.55
2100	Off white	Fairly hard	5.5	23.3	2.56
2200	Lt. ivory	Steel hard	11.0	14.0	2.54
2300	Ivory	Steel hard	15.0	7.8	2.50
2400	Ivory	Steel hard	15.0	6.3	2.46

Bloating Test: Negative

Pyrometric cone equivalent: Cone 32. **Cone color:** White.

Potential Uses: Unwashed sample: high-duty refractory products, ceramic ware such as whiteware, dinnerware, etc., if pale ivory color is acceptable.

Washed sample: decorative brick and tile, chimney flue tile, high-duty refractory products, ceramic whiteware, white cement, filler for plastic, paint, and probably low-grade paper coater.

Remarks: Washed sample: clay—88.1%; residue (mostly coarse quartz)—11.9%.

BUCKS COUNTY

Sample Number

207-2-1

Quadrangle: Quakertown 15′; Quakertown 7½′

Location: Quarry operated by the Quakertown Brick Company about one mile north of Quakertown along Heller Road.

Geologic Unit: Brunswick Formation, Triassic Age

Description: Two feet of clay overlying dark-reddish-brown shales are exposed in a quarry. The clay consists of two parts, an upper zone of mottled-orange and light-gray clay which is about 17 inches thick, and a lower 7 inch zone of red clay. The shale beds range in thickness from less than one inch up to about one foot. The height of the exposed working faces is about 10 feet. The soil overburden which is about one foot thick is removed as waste before the underlying material is quarried.

Attitude of Bedding: N13W; 25W

Sampled Interval: 10 foot channel sample

Type of Material: clay and shale

Chemical Analysis:

	%
SiO_2	56.40
Al_2O_3	19.50
Fe_2O_3	7.75
FeO	1.04
CaO	.44
MgO	1.92
K_2O	3.70
Na_2O	3.15
TiO_2	.88
L.O.I.	5.20
S	.014
CO_2	.26
comb. H_2O	4.07
H_2O @ 120°C	.87

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	23	6
Mica	45	8
Kaolinite	1	3
C-V-Mo	4	3
Feldspar	6	3

Other Tests:

pH: 7.3
Workability: fairly plastic and smooth, slightly short
Water of plasticity %: 21.0
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Fairly hard	7.5	10.3	2.62
1900	Brown	Very hard	10.0	7.7	2.60
2000	Brown red	Steel hard	12.5	3.0	2.53
2100	Brown	Expanded and melted			

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.02	125.8	3.7	No bloating
2000	1.61	100.3	2.9	No bloating
2100	1.05	65.4	1.5	Fair expansion, slightly sticky
2200	1.09	67.9	2.0	Fair expansion, very sticky

Evaluation: Might have a potential as sintered lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Unweathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	37.3
—1/4 + 1/8	35.4
—1/8 + 16	27.3
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	21.0
—3/8 + 1/4	50.0
—1/4 + 8	20.2
— 8 + 16	6.0
—16 + 35	2.2
—35 + 65	.3
—65	.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1890	1940
Optimum	1890	1965
Maximum	1950	2030

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	106
Fired	67
Effect of quenching	NA
Processing characteristics	Poor
Material flow	U
Point of release	10:00
Particle shape	Angular & Rounded
Pore structure	Fine
Expansion	Poor
Uniformity of firing	NU
Color	Lt. br. to br.

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft³*	*% Abs.*
—3/4 + 1/2	1.98	123.4	41.7
—1/2 + 1/4	1.60	99.7	25.0
—1/4 + 8 mesh	1.67	104.0	22.9

Screen analysis

Size	*Percent retained*
+3/8	3.8
—3/8 + 1/4	26.6
—1/4 + 8	25.3
— 8 + 16	19.5
—16 + 35	12.7
—35 + 65	6.1
—65	6.0
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	*NA
Lb/Ft³	NA
Compression (PSI)	NA
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	NA

Bags Cement/Yd.	7
Bulk Sp. Gr.	2.00
Lb/Ft³	124
Compression (PSI)	2601
Color (colorimeter)	52
Cure	Autoclave
% Abs.	9.4

* block crumbled—possibly high alkali.

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	5	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.58	Bulk Sp. Gr.	1.67
Lb/Ft^3	98	Lb/Ft^3	104
Compression (PSI)	2422	Compression (PSI)	4169
Color (colorimeter)	41	Color (colorimeter)	42
Cure	28 Day Steam	Cure	28 Day Steam
% Abs.	7.8	% Abs.	10.1

Potential Uses: Brick and tile

Remarks: Bloating tests (quick-firing) indicated this material might have potential as a sintered aggregate but subsequent rotary kiln and sintering tests gave poor results.

BUTLER COUNTY

Sample Number

15-2-1

Quadrangle: Zelienople 15'

Location: Garner Coal Company stripping operation about 0.9 mile south-southeast of Portersville Station and about 0.3 mile north of Bear Run, a stream tributary into Muddy Creek.

Geologic Unit: Middle Kittanning horizon, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-dark-gray to dark-gray silty shales and siltstones occur stratigraphically from 0 to about 15 feet above the top of the Middle Kittanning coal. The bedding in the siltstones is poorly defined except where beds containing up to approximately 5 percent of siderite nodules occur in the lower 4 feet of the section. The rock breaks into irregular, sharp-edged fragments. Iron oxide colors are common along joint surfaces.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 8-foot channel sample taken up from the top of the Middle Kittanning coal.

Type of Material: silty shale and siltstone

Chemical Analysis:

	%
SiO_2	56.65
Al_2O_3	19.00
Fe_2O_3	2.91
FeO	6.08
CaO	.48
MgO	1.49
K_2O	3.01
Na_2O	.27
TiO_2	.90
L.O.I.	9.16
S	.40
CO_2*	4.60
comb. H_2O	4.56
H_2O @ 120°C	.34

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	35	8
Mica	37	8
Kaolinite	13	8
C-V-Mo	4	3
Feldspar	1	2

Remarks: siderite, calcite and some montmorillonite (Mo) present

Other Tests:

pH: 8.05
Workability: not plastic, short, fatty and gritty
Water of plasticity %: 20.8
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	4.5	18.3	2.68
1900	Dk. buff brown	Soft, crumbly	4.5	15.6	2.68
2000	Brown	Very hard	6.0	11.6	2.68
2100	Dk. brown	Steel hard	11.0	3.4	2.55
2200	Very dk. brown	Steel hard	6.0	3.6	2.23
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.76	109.6	10.2	No bloating
2000	1.21	75.4	14.3	Fair bloating
2100	1.14	71.0	12.7	Fair bloating
2200	0.93	57.9	13.5	Overbloated and sticky
2300	0.64	39.9	12.5	Overbloated and sticky

Evaluation: The shale has layers of impurities which fuse at a low temperature. The bloating range is rather short.

Potential Uses: Brick and possibly floor tile.

BUTLER COUNTY

Sample Number

15-2-1A

Quadrangle: Zelienople 15'

Location: Garner Coal Company stripping operation about 0.9 mile south-southeast of Portersville Station and about 0.3 mile north of Bear Run, a tributary to Muddy Creek.

Geologic Unit: Middle Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray to dark-gray underclay of the Middle Kittanning coal is exposed in the floor of the strip mine. The thickness of the underclay is not known but it is at least 10 inches thick as measured in the floor of the stripping operation.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Grab sample collected from exposures in the floor of the strip mine.

Type of Material: underclay

Chemical Analysis:

	%
SiO_2	57.10
Al_2O_3	25.65
Fe_2O_3	2.49
FeO	.99
CaO	.19
MgO	.78
K_2O	3.06
Na_2O	.31
TiO_2	1.14
L.O.I.	8.26
S	.81
CO_2*	1.25
comb. H_2O	7.01
H_2O @ 120°C	1.15

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	6
Mica	46	8
Kaolinite	9	5
C-V-Mo	1	3
Feldspar	0	2

Other Tests:

pH: 4.3
Workability: not very plastic, short and gritty
Water of plasticity %: 18.5
% Drying shrinkage: 5.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. buff	Soft, crumbly	5.0	12.3	2.57
1900	Lt. buff	Fairly hard	5.0	12.8	2.57
2000	Lt. buff	Hard	5.0	11.2	2.60
2100	Lt. tan red	Steel hard	9.0	7.8	2.57
2200	Lt. tan	Steel hard	11.0	0.2	2.46
2300	Tan gray	Steel hard	Exp.	0.4	2.21

Bloating Test: Negative

Potential Uses: Possibly decorative brick and tile.

BUTLER COUNTY

Sample Number

25-5-1

Quadrangle: Butler 15'

Location: Exposure on the north side of Butler along the south side of the new route for U. S. Highway 422 and about 0.2 mile northwest of Calvary Cemetery.

Geologic Unit: Mahoning horizon, Conemaugh Formation, Pennsylvanian Age

Description: Interbedded carbonaceous and calcareous, platy to fissile shales and thin-bedded shales and siltstones occur between the upper and lower Mahoning sandstone members. Orange-tan iron-staining is common along fracture and bedding planes.

Sampled Interval: 12-foot channel sample

Type of Material: shales and siltstones

Chemical Analysis:

	%
SiO_2	56.80
Al_2O_3	18.80
Fe_2O_3	4.23
FeO	4.86
CaO	.43
MgO	1.22
K_2O	3.12
Na_2O	.49
TiO_2	.96
L.O.I.	9.04
S	.16
CO_2*	5.43
comb. H_2O	3.61
H_2O @ 120°C	.65

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	39	6
Mica	36	8
Kaolinite	13	8
C-V-Mo	2	3
Feldspar	1	3

Remarks: carbonate minerals present

Other Tests:

pH: 7.5
Workability: not plastic, short, mealy and gritty
Water of plasticity %: 18.2
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	0.5	20.9	2.69
1900	Brown	Soft, crumbly	0.5	19.0	2.67
2000	Brown	Soft, crumbly	4.5	18.3	2.65
2100	Dk. brown	Very hard	5.5	7.6	2.63
2200	Very dk. brown	Steel hard	5.5	4.5	2.54

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.04	127.1	7.8	No bloating
2000	1.70	105.9	9.7	No bloating
2100	1.04	64.8	24.2	Good bloating
2200	0.81	50.5	20.9	Excellent bloating, slightly sticky
2300	0.59	36.8	27.2	Overbloated and very sticky

Evaluation: The bloating range is rather short but with close temperature control this material will probably make a good lightweight aggregate by the rotary-kiln process.

Potential Uses: Good lightweight aggregate.

Remarks: Acid treatment shows considerable calcareous material.

BUTLER COUNTY

Sample Number

25-5-2

Quadrangle: Butler 15'; Saxonburg 7½'

Location: Exposure along the south side of U. S. Route 422, about 0.5 mile northwest of Mitchell School which is north of the Benjamin Franklin Highway as shown on the Saxonburg (7½') topographic map.

Geologic Unit: Lower Freeport underclay, Freeport Formation, Allegheny Group, Pennsylvanian Age

Description: A 6½-foot-thick, medium-light-gray to medium-gray underclay to the Lower Freeport coal is exposed for a distance of about 500 feet along the roadway. The underclay is commonly stained iron-brown along fractures. The clay breaks readily into small hackly fragments except where several local thin bands of hard flint clay occur.

Attitude of Bedding: Very gentle dip to southwest (essentially horizontal)

Sampled Interval: 6½-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	55.80
Al_2O_3	22.50
Fe_2O_3	3.96
FeO	2.58
CaO	1.35
MgO	.70
K_2O	2.59
Na_2O	.28
TiO_2	1.23
L.O.I.	8.98
S	.29
CO_2*	2.00
comb. H_2O	6.98
H_2O @ 120°C	1.46

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	8
Mica	42	10
Kaolinite	3	3
C-V-Mo	1	3
Feldspar	0	1

Remarks: calcite and dolomite present

Other Tests:

pH: 7.2
Workability: fairly plastic and smooth
Water of plasticity %: 20.7
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Hard	5.0	14.3	2.65
1900	Dk. buff brown	Very hard	5.0	13.8	2.65
2000	Dk. buff brown	Very hard	5.5	12.6	2.64
2100	Brown	Steel hard	10.0	9.5	2.60
2200	Dk. brown	Steel hard	10.0	6.1	2.50
2300	Gray black	Steel hard	10.0	1.9	2.27

Bloating Test: Negative

Potential Uses: Possibly brick.

BUTLER COUNTY

Sample Number

25-5-3A

Quadrangle: Butler 15'; Saxonburg 7½'

Location: Exposure along the south side of U. S. Route 422, about 0.4 mile northwest of Mitchell School which is located north of the Benjamin Franklin Highway (see Saxonburg topographic map).

Geologic Unit: Mahoning horizon, Conemaugh Formation, Pennsylvanian Age

Description: Dark-gray, carbonaceous, fissile shale and very-thin-bedded siltstone occur above the Upper Freeport coal for a distance of about 18 stratigraphic feet. An occasional thin band of siderite, up to ½ inch thick, occurs in the section. The siderite content makes up about 5 percent of the section.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	52.50
Al_2O_3	17.30
Fe_2O_3	4.29
FeO	6.92
CaO	.53
MgO	1.25
K_2O	2.92
Na_2O	.34
TiO_2	.92
L.O.I.	12.98
S	.42
CO_2*	11.57
comb. H_2O	1.41
H_2O @ 120°C	.58

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	37	8
Mica	39	8
Kaolinite	12	6
C-V-Mo	2	2
Feldspar	1	2

Remarks: siderite and other carbonates present

Other Tests:

pH: 6.7
Workability: not plastic, short, mealy and gritty
Water of plasticity %: 15.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Med. brown	Soft, crumbly	2.0	20.2	2.69
1900	Med. brown	Soft, crumbly	2.0	11.5	2.68
2000	Med. brown	Hard	5.0	17.5	2.68
2100	Dk. brown	Steel hard	5.0	8.2	2.64
2200	Gray black	Steel hard	5.0	3.8	2.50
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.37	85.4	12.7	Slight bloating
2000	1.00	62.3	4.9	Good bloating, slightly sticky
2100	0.67	41.7	22.8	Overbloated and sticky
2200	0.65	40.5	21.7	Overbloated and very sticky
2300	0.57	35.5	25.5	Overbloated and very sticky

Evaluation: Probably fair lightweight aggregate. The shale has layers of low-fusion material. The bloating range is rather short.

Potential Uses: Fair lightweight aggregate.

CARBON COUNTY

Sample Number

195-2-3

Quadrangle: Lehighton 15'; Christmans 7½'

Location: East side of the northeast extension of the Pennsylvania Turnpike about 5.5 miles northeast of Jim Thorpe and about 0.15 mile south of the place where the tributary to Wild Creek passes under the Turnpike.

Geologic Unit: Catskill Formation, Susquehanna Group, Devonian Age

Description: Grayish-red and dark-greenish-gray interbedded shales and siltstones with beds ranging in thickness from 4 to 18 inches. The weathered fragments on the slope are predominantly tabular in shape with angular edges and measure, on the average, from 3 to 4 inches in their long dimension. The roadcut extends for a distance of 430 feet and exposes about 27 feet of stratigraphic section which lies structurally within a relatively broad anticline.

Sampled Interval: Grab sample covering entire 430 feet of exposed roadcut with chips taken at hammer-length intervals.

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	64.50
Al_2O_3	17.20
Fe_2O_3	4.20
FeO	3.95
CaO	.17
MgO	1.23
K_2O	3.71
Na_2O	.32
TiO_2	.99
L.O.I.	3.72
S	.014
CO_2*	.15
comb. H_2O	3.53
H_2O @ 120°C	.03

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	37	8
Mica	38	8
Kaolinite	15	8
C-V-Mo	3	2
Feldspar	1	2

Remarks: some montmorillonite (Mo) and carbonates present

Other Tests:

pH: 8.5
Workability: not plastic, short, mealy, fine grit
Water of plasticity %: 20.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Brown buff	Soft, crumbly	1.5	18.1	2.59
1900	Brown	Soft, crumbly	5.5	16.1	2.64
2000	Brown	Soft, crumbly	5.5	15.4	2.63
2100	Med. brown	Hard	9.0	12.7	2.63
2200	Dk. gray brown	Steel hard	11.0	3.2	2.50
2300	Dk. gray	Steel hard	Exp.	7.1	2.47

Bloating Test: Slight expansion

Potential Uses: Sintered aggregate.

Remarks: Acid treatment shows small amount of calcareous material.

CARBON COUNTY

Sample Number

195-5-2

Quadrangle: Lehighton 15'; Lehighton 7½'

Location: East side of the northeast extension of the Pennsylvania Turnpike about 0.6 mile northeast of Harrity.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: Exposure consists of medium- to medium-dark-gray, thin-bedded, fossiliferous shales. The beds range from less than one inch to eighteen inches in thickness and the shale weathers into platy fragments which average several inches in their long dimension. Light-brown to moderate-brown stains occur along fractures and in fossil impressions. The fossils are typical of the Hamilton Group and include crinoids, brachiopods and bryozoans. The exposure extends for a distance of about 750 feet along the Turnpike and is about 40 feet high.

Attitude of Bedding: N62E; 32 SE

Sampled Interval: Grab sample taken from entire exposure with sample chips collected every 5 feet.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.00
Al_2O_3	18.15
Fe_2O_3	4.08
FeO	3.34
CaO	.90
MgO	1.19
K_2O	4.03
Na_2O	.62
TiO_2	.91
L.O.I.	5.77
S	.058
CO_2*	1.94
comb. H_2O	3.47
H_2O @ 120°C	.30

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	43	6
Mica	33	8
Kaolinite	12	6
C-V-Mo	4	3
Feldspar	1	2

Other Tests:

pH: 8.8
Workability: not plastic, short and mealy
Water of plasticity %: 20.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	19.6	2.67
1900	Brown	Soft, crumbly	5.0	15.8	2.60
2000	Brown	Hard	5.0	14.6	2.63
2100	Dk. brown red	Very hard	6.0	10.8	2.59
2200	Dk. brown gray	Steel hard	6.0	4.9	2.25
2300	Gray black	Steel hard	Exp.	4.7	1.98

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.36	84.7	14.6	Slight bloating
2000	1.07	66.7	24.3	Fair bloating
2100	0.75	46.7	47.0	Good bloating
2200	0.58	36.1	7.3	Overbloated and slightly sticky

Evaluation: Good lightweight aggregate.

Potential Uses: Good lightweight aggregate.

Remarks: Acid treatment shows a small amount of calcareous material.

CARBON COUNTY

Sample Number

195-7-1

Quadrangle: Lehighton 15'; Lehighton 7½'

Location: Exposure along the east side of the Northeast Extension of the Pennsylvania Turnpike, about 0.4 mile west of Bowmanstown.

Geologic Unit: Marcellus Formation, Hamilton Group, Devonian Age

Description: Medium- to medium-dark-gray, predominantly fissile, carbonaceous shales are exposed for a distance of about 750 feet along the Turnpike. Two zones of non-fissile shales, each about 25 feet wide, occur in the section. Beds in these zones measure up to 2 feet in thickness. The fissile shale breaks easily into very platy fragments with angular edges. Weathered fracture surfaces are commonly olive gray. The exposure is about 25 feet high.

Attitude of Bedding: N72E; 55-70S

Sampled Interval: Grab sample (north from the weathered contact of the Marcellus Formation with the underlying Onondaga Formation for a distance of 415 feet along the Turnpike)

Type of Material: shale

Chemical Analysis:

	%
SiO_2	58.00
Al_2O_3	17.85
Fe_2O_3	3.59
FeO	3.42
CaO	1.04
MgO	1.17
K_2O	3.85
Na_2O	.56
TiO_2	.86
L.O.I.	9.64
S	.79
CO_2*	5.60
comb. H_2O	2.89
H_2O @ 120°C	.36

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	39	8
Mica	45	8
Kaolinite	10	6
C-V-Mo	2	3
Feldspar	0	2

Other Tests:

pH: 6.0
Workability: not plastic, short and mealy
Water of plasticity %: 17.0
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown buff	Soft, crumbly	1.5	22.6	2.66
1900	Brown buff	Fairly hard	5.0	20.4	2.59
2000	Brown buff	Hard	5.0	18.9	2.57
2100	Brown	Very hard	5.5	16.3	2.51
2200	Dk. brown gray	Steel hard	Exp.	17.0	1.72

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Poor (very platy) Particle size: —½ + ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.87	116.5	8.7	No bloating
2000	1.70	105.9	9.6	No bloating
2100	1.18	73.5	15.5	Good bloating
2200	0.77	48.0	16.2	Overbloated, sticky and fragile

Evaluation: Possibly sintered aggregate; crushing characteristics of this material are very poor.

Potential Uses: Possibly sintered aggregate.

Remarks: Acid treatment shows a small amount of calcareous material.

CLARION COUNTY

Sample Number

44-2-1

Quadrangle: Clarion 15'

Location: About 1.75 miles south of Clarion and approximately 500 feet west of Route 68 on the south side of the unimproved road which parallels Courtleys Run.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray, plastic underclay which is believed to be the equivalent of the Vanport limestone is exposed at this location. The clay is reported to be 10 feet thick and overlies the Clarion sandstone. Mottled brown, gray, and dark-gray blotches are common within the underclay. Clay fragments at the surface are angular and average about 2½ inches in size.

Sampled Interval: Grab sample collected from the upper part of the underclay which is exposed at the surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	58.15
Al_2O_3	27.70
Fe_2O_3	.77
FeO	.46
CaO	.05
MgO	.15
K_2O	.52
Na_2O	.26
TiO_2	1.40
L.O.I.	10.49
S	.096
CO_2*	.88
comb. H_2O	8.72
H_2O @ 120°C	.79

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	10
Mica	23	10
Kaolinite	35	12
C-V-Mo	2	2
Feldspar	0	3

Remarks: goethite present (?)

Other Tests:

pH: 5.2
Workability: fair plasticity, short and gritty
Water of plasticity %: 22.0
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	6.0	17.3	2.58
1900	Very lt. buff	Soft, crumbly	6.0	17.3	2.62
2000	Very lt. buff	Soft, crumbly	6.0	16.4	2.60
2100	Lt. gray	Soft, crumbly	6.0	15.6	2.59
2200	Lt. gray	Soft, crumbly	6.5	14.2	2.63
2300	Lt. gray	Hard	8.5	13.6	2.61

Bloating Test: Negative

Pyrometric cone equivalent: 31-32 **Cone color:** Gray

Potential Uses: High-duty refractory products.

CLARION COUNTY

Sample Number

44-4-2A

Quadrangle: Clarion 15′

Location: About 4.0 miles northeast of Sligo and about 0.5 mile north of Larimar School which is located along the road from Reidsville to Sligo.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Light-gray, plastic clay which represents the underclay to the Lower Kittanning coal makes up a pile of broken rock at this location.

Sampled Interval: Grab sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	67.40
Al_2O_3	19.10
Fe_2O_3	1.43
FeO	.68
CaO	.07
MgO	.50
K_2O	3.03
Na_2O	.38
TiO_2	1.15
L.O.I.	6.25
S	.35
CO_2*	.53
comb. H_2O	4.72
H_2O @ 120°C	.65

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	57	8
Mica	30	6
Kaolinite	6	4
C-V-Mo	2	2
Feldspar	1	3

Other Tests:

pH: 6.9
Workability: plastic and smooth
Water of plasticity %: 21.0
% Drying shrinkage: 4.5
Dry strength: above average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. red brown	Soft, crumbly	5.0	14.5	2.51
1900	Lt. red brown	Soft, crumbly	5.0	13.5	2.53
2000	Lt. tan buff	Very hard	6.5	9.8	2.51
2100	Lt. tan	Steel hard	10.0	11.3	2.50
2200	Lt. brown	Steel hard	10.0	3.6	2.41
2300	Lt. brown gray	Steel hard	10.0	1.2	2.23

Bloating Test: Negative

Pyrometric cone equivalent: 22-23 **Cone color:** Gray

Potential Uses: Decorative tile, decorative brick, and pottery. Possibly low-duty products such as ladle brick and chimney flue tile.

Remarks: Excellent working properties for brick and tile.

CLARION COUNTY

Sample Number

44-4-2B

Quadrangle: Clarion 15'

Location: About 4.0 miles northeast of Sligo and about 0.5 mile north of Larimar School which is located along the road between Reidsville and Sligo.

Geologic Unit: Hamden Shale Member, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-dark to dark-gray, carbonaceous shales of the middle and upper units of the Hamden are exposed in this stripping. The middle unit is one foot thick at this locality but the upper unit is represented by 17 feet of thin-bedded shale which becomes silty in the upper 5 feet. With weathering the shale breaks into hackly fragments which average about 2 inches in length. Siderite nodules occur throughout the section and make up about 3 to 5 percent of the volume. Neither the siderite nor the upper five feet of silty material were included in the sampled material.

Attitude of Bedding: Gentle dip to south

Sampled Interval: 13-foot channel sample consisting of the one-foot middle unit and the lower 12 feet of the upper unit

Type of Material: shale

Chemical Analysis:

	%
SiO_2	52.60
Al_2O_3	20.50
Fe_2O_3	2.95
FeO	5.32
CaO	.67
MgO	1.33
K_2O	3.31
Na_2O	.66
TiO_2	.97
L.O.I.	11.65
S	.74
CO_2*	7.10
comb. H_2O	3.09
H_2O @ 120°C	.72

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	26	6
Mica	50	8
Kaolinite	12	8
C-V-Mo	2	2
Feldspar	1	2

Other Tests:

pH: 7.2
Workability: not plastic, short and mealy
Water of plasticity %: 17.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	4.0	15.0	2.61
1900	Dk. buff brown	Soft, crumbly	6.0	13.3	2.60
2000	Brown red	Steel hard	6.0	9.8	2.55
2100	Dk. brown red	Steel hard	9.5	6.6	2.50
2200	Very dk. brown	Steel hard	Exp.	6.3	2.15
2300	Melted and expanded				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.31	81.6	13.3	Fair bloating
2000	0.90	56.1	17.4	Good bloating
2100	0.78	48.6	16.5	Excellent bloating
2200	0.50	31.2	22.2	Overbloated, fragile, slightly sticky

Evaluation: Excellent lightweight aggregate material.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Fair
Particle shape	Platy
Particle thickness	Uniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
−3/8 + 1/4	58.0
−1/4 + 1/8	27.2
−1/8 + 16	14.8
Total	100.0

Screen analysis

Size	Percent retained
+3/8	23.1
−3/8 + 1/4	36.9
−1/4 + 8	17.3
− 8 + 16	9.4
−16 + 35	7.4
−35 + 65	4.1
−65	1.8
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1850	1900
Optimum	1910	1990
Maximum	1999	2079

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	97
Fired	46
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	11:00
Particle shape	Angular
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt br. to gray

Specific gravity, weight, absorption

Size	ASG	Lb/Ft.³	% Abs.
−3/4 + 1/2	NA	NA	NA
−1/2 + 1/4	1.42	88.5	1.73
−1/4 + 8 mesh	1.36	84.7	1.03

Screen analysis

Size	Percent retained
+3/8	8.2
−3/8 + 1/4	58.7
−1/4 + 8	25.8
− 8 + 16	5.5
−16 + 35	1.1
−35 + 65	.4
−65	.3
Total	100.0

oncrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.58
Lb/Ft³	98
Compression (PSI)	3373
Color (colorimeter)	19
Cure	Autoclave
% Abs.	8.8

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft³	92
Compression (PSI)	2725
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	4.2

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.60	Bulk Sp. Gr.	1.56
Lb/Ft^3	100	Lb/Ft^3	97
Compression (PSI)	2504	Compression (PSI)	4601
Color (colorimeter)	9	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	9.0	% Abs.	5.6

Potential Uses: Good lightweight aggregate; possibly brick.

Remarks: Bloating tests (quick-firing) indicated this material would make an excellent lightweight aggregate, but the results of rotary kiln tests on a bulk sample indicated that it should be classified as good lightweight aggregate.

CLARION COUNTY

Sample Number

44-4-2C

Quadrangle: Clarion 15′

Location: About 4.0 miles northeast of Sligo and about 0.5 mile north of Larimar School which is located along a road between Reidsville and Sligo.

Geologic Unit: Hamden Shale Member, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-dark to dark-gray carbonaceous shales which represent the lower unit of the Hamden are exposed at this location. The shale becomes siltier towards the bottom and breaks up into hackly fragments which measure, on the average, about 2 inches in length. The rock is more resistant than the rock in the overlying middle unit of the Hamden. The total thickness of the lower unit at this locality is 3 feet.

Attitude of Bedding: Beds dip very gently southward

Sampled Interval: Channel sample from 0 to 3 feet above Lower Kittanning coal

Type of Material: shale

Chemical Analysis:

	%
SiO_2	51.35
Al_2O_3	19.35
Fe_2O_3	6.40
FeO	2.89
CaO	.35
MgO	1.26
K_2O	3.34
Na_2O	.68
TiO_2	1.00
L.O.I.	13.36
S	1.41
CO_2*	8.20
comb. H_2O	2.94
H_2O @ 120°C	.81

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	29	8
Mica	48	10
Kaolinite	10	7
C-V-Mo	3	3
Feldspar	1	3

Other Tests:

pH: 5.0
Workability: not plastic, short and mealy
Water of plasticity %: 17.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	4.0	22.2	2.60
1900	Dk. buff brown	Soft, crumbly	4.0	14.8	2.58
2000	Red brown	Steel hard	6.5	10.5	2.55
2100	Dk. brown red	Steel hard	9.5	6.4	2.43
2200	Dk. brown	Steel hard	Exp.	6.7	1.84
2300	Expanded and melting				

Bloating Test: Slight expansion.

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.97	122.7	7.2	No bloating
2000	1.92	119.6	5.5	No bloating
2100	1.57	97.8	9.7	Slight expansion
2200	1.26	78.5	11.7	Fair bloating

Evaluation: Possibly sintered aggregate.

Potential Uses: Brick and tile; possibly sintered aggregate.

CLARION COUNTY

Sample Number

44-4-3

Quadrangle: Clarion 15'

Location: About 1.25 miles southeast of Sligo, midway between Little Licking Creek and the road to the north which connects Sligo and Curllsville.

Geologic Unit: Upper Clarion horizon, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray, very-thin-bedded shale overlies the Upper Clarion coal for a stratigraphic distance of 18 feet. The shale contains an estimated 5 to 10 percent of siderite nodules, the largest of which measure 6 inches. The shale breaks up into angular, platy fragments which average about 2 inches in length. Exposed surfaces of the shale are commonly weathered yellow-brown.

Sampled Interval: Grab sample (fragments collected at hammer-length intervals through the 18 feet of shale)

Type of Material: shale

Chemical Analysis:

	%
SiO_2	55.00
Al_2O_3	21.00
Fe_2O_3	3.25
FeO	3.50
CaO	.48
MgO	1.20
K_2O	2.78
Na_2O	.56
TiO_2	1.00
L.O.I.	11.17
S	.89
CO_2*	7.76
comb. H_2O	1.65
H_2O @ 120°C	.87

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	29	6
Mica	48	8
Kaolinite	13	6
C-V-Mo	1	2
Feldspar	0	2

Other Tests:

pH: 6.6
Workability: not plastic, short and mealy
Water of plasticity %: 18.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	6.0	13.5	2.58
1900	Dk. buff brown	Soft, crumbly	6.0	12.3	2.58
2000	Red brown	Steel hard	8.0	8.1	2.55
2100	Dk. brown red	Steel hard	10.0	4.5	2.50
2200	Dk. brown	Steel hard	10.0	3.4	2.18
2300	Expanded and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.59	99.1	9.0	No bloating
2000	1.39	86.6	9.0	Slight bloating
2100	0.70	43.6	24.8	Good bloating
2200	0.47	29.3	42.7	Overfired, melting and sticky

Evaluation: Possibly fair lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Fair
Particle shape	Angular
Particle thickness	Uniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	46.0
—1/4 + 1/8	32.6
—1/8 + 16	21.4
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	17.2
—3/8 + 1/4	26.1
—1/4 + 8	18.5
— 8 + 16	12.2
—16 + 35	14.4
—35 + 65	8.8
—65	2.8
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1890	1940
Optimum	1940	1980
Maximum	1991	2070

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	110
Fired	49
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Platy
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Tan to gray

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.44	89.7	6.23
—1/2 + 1/4	1.43	89.1	6.12
—1/4 + 8 mesh	1.28	79.7	3.62

Screen analysis

Size	*Percent retained*
+3/8	18.8
—3/8 + 1/4	53.8
—1/4 + 8	22.8
— 8 + 16	3.5
—16 + 35	.6
—35 + 65	.3
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.71
Lb/Ft^3	106
Compression (PSI)	3973
Color (colorimeter)	10
Cure	Autoclave
% Abs.	13.3

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.55
Lb/Ft^3	96
Compression (PSI)	3468
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	5.1

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.87	Bulk Sp. Gr.	1.71
Lb/Ft^3	117	Lb/Ft^3	107
Compression (PSI)	6304	Compression (PSI)	5009
Color (colorimeter)	13	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	14.9	% Abs.	6.6

Potential Uses: Brick and tile; fair lightweight aggregate.

Remarks: Acid treatment shows the presence of a small amount of calcareous material.

CLARION COUNTY

Sample Number

44-8-4

Quadrangle: Clarion 15'

Location: About 2 miles northwest of New Bethlehem and 0.3 mile south of the road connecting Cottage Hill and Smithland.

Geologic Unit: Middle Kittanning horizon, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray, thin-bedded shale occurs for a stratigraphic distance of ten feet above the Middle Kittanning coal. Faint purple and dark-gray mottling and thin beds of siderite occur locally in the section. The shale weathers to small, very thin plates. This unit grades upward into a very carbonaceous, coal-like shale.

Attitude of Bedding: Gentle dip to the northeast

Sampled Interval: Channel sampled for nine feet above the Middle Kittanning coal

Type of Material: shale

Chemical Analysis:

	%
SiO_2	53.50
Al_2O_3	20.10
Fe_2O_3	2.56
FeO	6.69
CaO	.41
MgO	1.17
K_2O	2.81
Na_2O	.68
TiO_2	.95
L.O.I.	11.08
S	.18
CO_2*	7.61
comb. H_2O	2.45
H_2O @ 120°C	.84

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	30	8
Mica	40	8
Kaolinite	17	8
C-V-Mo	3	3
Feldspar	1	2

Remarks: some siderite present

Other Tests:

pH: 6.7
Workability: fair plasticity, short
Water of plasticity %: 22.0
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.5	16.6	2.66
1900	Brown	Soft, crumbly	5.5	15.4	2.66
2000	Brown red	Steel hard	9.5	10.8	2.63
2100	Dk. brown	Steel hard	11.0	5.6	2.58
2200	Very dk. brown	Steel hard	11.0	1.6	2.48
2300	Gray black	Steel hard	Exp.	1.5	2.05

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.38	86.0	8.9	No bloating
2000	1.14	71.0	9.2	Fair bloating
2100	1.08	67.3	10.1	Good expansion
2200	0.32	19.9	22.7	Overbloated, melting, very sticky

Evaluation: Fair lightweight aggregate.

Potential Uses: Fair lightweight aggregate; possibly brick.

Remarks: Fired colors are not very attractive; acid treatment shows the presence of a small amount of calcareous material.

CLEARFIELD COUNTY

Sample Number

85-2-3

Quadrangle: Houtzdale 15'; Glen Richey 7½'

Location: Property owned by the Maple Hill Coal Company, located about 1 mile southwest of Mineral Springs.

Geologic Unit: Clarion underclay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Drill core of Clarion underclay obtained from a vertical hole which penetrated 100 inches of soft, medium-gray clay below the Clarion coal.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Core split for sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	57.00
Al_2O_3	25.90
Fe_2O_3	1.42
FeO	1.64
CaO	.13
MgO	.47
K_2O	2.95
Na_2O	.60
TiO_2	1.50
L.O.I.	8.32
S	.41
CO_2	2.00
comb. H_2O	6.07
H_2O @ 120°C	.25

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	37	8
Mica	36	10
Kaolinite	14	8
C-V-Mo	3	3
Feldspar	1	2

Other Tests:

pH: 5.8
Workability: slightly plastic, gritty and very short, hardens on standing
Water of plasticity %: 17.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	2.0	19.1	2.69
1900					
2000	Lt. buff	Soft, crumbly	2.5	15.9	2.69
2100	Lt. buff ivory	Steel hard	4.0	12.8	2.68
2200	Lt. tan	Steel hard	5.0	9.4	2.63
2300	Gray tan	Steel hard	7.5	7.4	2.51
2400	Gray	Steel hard	7.5	8.0	2.45

Bloating Test: Negative

Pyrometric cone equivalent: 29-30 **Cone color:** Light gray

Potential Uses: Intermediate-duty refractory products and chimney flue tile; possibly decorative brick.

CLEARFIELD COUNTY

Sample Number

85-3-4

Quadrangle: Houtzdale 15'; Wallaceton 7½'

Location: Maple Hill Coal Company stripping operation about 0.4 mile southwest of Bigler.

Geologic Unit: Middle Kittanning horizon, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Thin-bedded, gray-black shales occur stratigraphically above the Middle Kittanning coal for a distance of 9.5 feet. Above this zone the beds become silty. The shale beds range in thickness from about 1 to 6 inches and are commonly iron-stained along fracture and bedding planes. The lowermost 6 to 8 feet of this shale zone contains from one to five per cent of siderite concretions. The long dimension of the stripping operations extends for a distance of about 800 feet.

Attitude of Bedding: Horizontal

Sampled Interval: Channel sampled from 0 to 9.5 feet stratigraphically above Middle Kittanning coal.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	54.90
Al_2O_3	22.35
Fe_2O_3	3.50
FeO	2.40
CaO	.20
MgO	1.03
K_2O	4.05
Na_2O	.50
TiO_2	.99
L.O.I.	10.02
S	.46
CO_2	9.09
comb. H_2O	.35
H_2O @ 120°C	.58

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	32	8
Mica	43	8
Kaolinite	15	8
C-V-Mo	2	2
Feldspar	1	2

Other Tests:

pH: 4.9
Workability: not plastic, short, gritty
Water of plasticity %: 20.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	2.5	21.6	2.62
1900	Lt. brown	Soft, crumbly	5.0	18.4	2.64
2000	Brown	Hard	7.5	13.5	2.59
2100	Dk. brown	Steel hard	9.0	9.5	2.56
2200	Dk. gray brown	Steel hard	9.0	3.6	2.36
2300	Dk. gray brown	Expanded and melting			

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.11	131.5	5.1	No bloating
1900	2.01	125.2	7.0	No bloating
2000	1.90	118.4	5.8	No bloating
2100	1.58	98.4	9.0	No bloating
2200	1.02	63.5	15.8	Fair expansion
2300				Melted

Evaluation: This shale is not suitable for lightweight aggregate material because of the high bloating temperature and the short firing range.

Potential Uses: Brick.

CLEARFIELD COUNTY

Sample Number

85-3-5

Quadrangle: Houtzdale 15'; Wallaceton 7½'

Location: General Refractories strip mine operation about 1.5 miles northwest of West Decatur P. O.

Geologic Unit: Clarion underclay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray underclay, 77 inches thick, occurs below the Clarion coal in this strip mine.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sampled from 0 to 77 inches stratigraphically below the Clarion coal.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	55.15
Al_2O_3	28.70
Fe_2O_3	1.06
FeO	.80
CaO	.15
MgO	.46
K_2O	2.20
Na_2O	.40
TiO_2	1.67
L.O.I.	9.36
S	.07
CO_2	1.57
comb. H_2O	7.16
H_2O @ 120°C	.63

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	37	10
Mica	25	10
Kaolinite	31	10
C-V-Mo	1	3
Feldspar	0	2

Remarks: Some calcite present

Other Tests:

pH: 6.2
Workability: fairly plastic, slightly short
Water of plasticity %: 19.0
% Drying shrinkage: 2.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	2.5	16.8	2.67
1900	Lt. buff	Fairly hard	2.5	14.1	2.69
2000					
2100	Lt. buff ivory	Steel hard	5.0	11.7	2.66
2200	Lt. tan	Steel hard	7.0	9.2	2.65
2300	Gray tan	Steel hard	7.5	8.0	2.61
2400	Gray	Steel hard	7.5	6.6	2.57

Bloating Test: Negative

Pyrometric cone equivalent: 30 **Cone color:** Light gray

Potential Uses: Intermediate-duty refractory products, decorative brick, tile, chimney flue tile.

CLEARFIELD COUNTY

Sample Number

85-5-2

Quadrangle: Houtzdale 15'; Ramey 7½'

Location: Stripping operation about 0.1 mile west of the road intersection south of Henderson.

Geologic Unit: Middle Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: A 47-inch-thick underclay occurs below the Middle Kittanning coal near the top of the quarry which is about 25 feet deep. The clay is gray-black in color but where weathered is yellow-brown. The quarry excavation is greater than 100 feet in width and 400 feet in length.

Attitude of Bedding: Horizontal

Sampled Interval: A 47-inch channel sample under the Middle Kittanning coal on the east wall of the stripping operation.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	61.50
Al_2O_3	19.80
Fe_2O_3	5.82
FeO	.84
CaO	.04
MgO	.65
K_2O	3.46
Na_2O	.44
TiO_2	.96
L.O.I.	6.45
S	.038
CO_2	1.46
comb. H_2O	4.99

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	42	10
Mica	32	10
Kaolinite	18	10
C-V-Mo	1	3
Feldspar	1	3

Remarks: carbonate minerals present

Other Tests:

pH: 5.05
Workability: fairly plastic and smooth
Water of plasticity %: 21.0
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Very lt. brown	Soft, crumbly	2.5	18.9	2.58
1900	Very lt. brown	Soft, crumbly	4.0	17.9	2.61
2000	Very lt. brown tan	Fairly hard	5.0	13.0	2.58
2100	Brown tan	Steel hard	7.5	10.0	2.57
2200	Dk. gray brown	Steel hard	10.0	3.3	2.50
2300	Dk. gray	Steel hard	10.0	2.0	2.50

Bloating Test: Negative

Potential Uses: Possibly decorative brick.

Remarks: The fired color at 2100°F is rather unusual. This clay might make an acceptable decorative brick if this color is acceptable to the trade.

CLEARFIELD COUNTY

Sample Number

85-5-6

Quadrangle: Houtzdale 15'; Wallaceton 7½'

Location: Mine located about 0.5 mile south-southwest of Burly and about 5 miles north of Houtzdale.

Geologic Unit: Mercer horizon, Pottsville Group, Pennsylvanian Age

Description: Medium-gray, nodular flint clay, 54 inches thick, is underlain by a medium-gray, softer clay which is 56 inches thick. The clays are exposed in mine pillars of a former underground operation.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Composite sample of clays from a mine pillar

Type of Material: clay

Chemical Analysis:

	%
SiO_2	40.70
Al_2O_3	40.57
Fe_2O_3	.53
FeO	.72
CaO	.16
MgO	.19
K_2O	1.35
Na_2O	.60
TiO_2	2.57
L.O.I.	12.59
S	.03
CO_2	1.14
comb. H_2O	11.15
H_2O @ 120°C	.30

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	5	5
Mica	25	10
Kaolinite	58	12
C-V-Mo	2	4
Feldspar	1	3

Remarks: some boehmite

Other Tests:

pH: 5.9
Workability: not plastic, short, slightly gritty, hardens on standing
Water of plasticity %: 17.0
% Dry shrinkage: 0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Specimen too crumbly to determine properties. Fired colors range from light buff to gray buff		1800-2400.		

Bloating Test: Negative

Pyrometric cone equivalent: 33 **Cone color:** Light tan

Potential Uses: Super-duty refractory products.

CLEARFIELD COUNTY

Sample Number

85-6-1

Quadrangle: Houtzdale 15'; Houtzdale 7½'

Location: Exposure in a quarry pit at an elevation of about 1580 feet above sea level on the northeast side of Little Beaver Run about 2.25 miles northeast of Houtzdale and 1.3 miles northwest of Beaverton.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: The underclay to the Lower Kittanning coal is exposed in a small pit which measures about 65 x 75 feet. The upper nine inches of the clay is limonite brown in color; below this horizon, the color of the clay is light gray and grades downward to medium gray.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sampled 52 inches of clay

Type of Material: clay

Chemical Analysis:

	%
SiO_2	57.45
Al_2O_3	27.00
Fe_2O_3	.97
FeO	.62
CaO	.27
MgO	.31
K_2O	2.59
Na_2O	.26
TiO_2	1.45
L.O.I.	9.04
S	.16
CO_2*	.90
comb. H_2O	7.21
H_2O @ 120°C	.77

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	10
Mica	27	10
Kaolinite	28	10
C-V-Mo	1	2
Feldspar	0	2

Other Tests:

pH: 5.3
Workability: fairly plastic and smooth
Water of plasticity %: 18.0
% Drying shrinkage: 0.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	0.5	17.5	2.58
1900					
2000	Lt. pink buff	Soft, crumbly	1.5	15.8	2.63
2100	Lt. pink buff	Fairly hard	4.5	10.1	2.59
2200	Lt. tan	Very hard	5.5	8.3	2.56
2300	Lt. gray tan	Steel hard	7.5	6.1	2.53
2400	Lt. gray	Steel hard	8.5	5.2	2.50

Bloating Test: Negative

Pyrometric cone equivalent: 30 **Cone color:** Light gray

Potential Uses: Intermediate-duty refractory products, decorative brick, tile and chimney flue tile.

CLEARFIELD COUNTY

Sample Number

95-4-1

Quadrangle: Philipsburg 15'; Philipsburg 7½'

Location: Exposure about 1.5 miles northwest of Philipsburg along the south side of U. S. Highway 322.

Geologic Unit: Upper Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-to medium-dark-gray underclay lies directly below the Upper Kittanning coal. The underclay is a maximum of 85 inches thick with the lower portion containing moderate amounts of limonite nodules. Laterally, the upper part of the underclay varies from two to four feet in thickness. The extent of the exposure is about 150 feet and its height is about 20 feet.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample through four feet of underclay

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.80
Al_2O_3	22.60
Fe_2O_3	2.35
FeO	.64
CaO	.80
MgO	.68
K_2O	3.40
Na_2O	.40
TiO_2	1.21
L.O.I.	8.05
S	.07
CO_2	2.13
comb. H_2O	5.85
H_2O @ 120°C	.32

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	43	8
Mica	38	8
Kaolinite	9	6
C-V-Mo	2	3
Feldspar	0	2

Remarks: carbonates and limonite present

Other Tests:

pH: 7.9
Workability: plastic and smooth
Water of plasticity %: 19.0
% Drying shrinkage: 1.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff	Soft, crumbly	4.5	17.3	2.72
1900	Buff	Soft, crumbly	5.5	11.8	2.56
2000	Buff brown	Steel hard	6.0	7.3	2.54
2100	Dk. buff brown	Steel hard	9.0	6.3	2.53
2200	Gray tan	Steel hard	11.0	3.4	2.47
2300	Gray	Steel hard	11.0	2.5	2.41

Bloating Test: Negative

Potential Uses: Decorative brick and tile if fired colors are acceptable to the trade.

Remarks: Mottled colors fairly attractive.

CUMBERLAND COUNTY

Sample Number

127-9-1

Quadrangle: Loysville 15'; Landisburg 7½'

Location: Outcrop located about 5 miles west of Carlisle Springs along the south side of the south leg of the fork intersection with State Route 74.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Thin-bedded, reddish-brown shales and siltstones that range in thickness from less than one inch to about four inches are exposed along the roadway. The rock breaks up into small chip-like fragments, usually less than one-half inch long. The outcrop extends along the roadway for a distance of 310 feet and is overlain by a soil overburden which is up to five feet in thickness.

Attitude of Bedding: Complex folding; the strike of bedding in general is N75E

Sampled Interval: Grab sample collected from 300 feet of exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	65.00
Al_2O_3	14.40
Fe_2O_3	4.92
FeO	2.46
CaO	.26
MgO	1.67
K_2O	3.23
Na_2O	1.50
TiO_2	.85
L.O.I.	5.64
S	.022
CO_2	.99
comb. H_2O	4.65

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	42	6
Mica	39	10
Kaolinite	0	2
C-V-Mo	5	4
Feldspar	5	3

Other Tests:

pH: 5.7
Workability: fair plasticity, short
Water of plasticity %: 21.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	4.0	15.2	2.67
1900	Dk. buff orange	Hard	5.0	13.3	2.64
2000	Brown red	Steel hard	10.0	6.0	2.55
2100	Dk. brown	Steel hard	10.0	3.6	2.43
2200	Expanded and melting				

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.92	119.6	7.7	No bloating
1900	1.70	105.9	5.4	No bloating
2000	1.62	100.9	5.7	Good expansion
2100	1.35	84.1	2.9	Excellent expansion
2200	1.29	80.3	5.8	Slightly overfired, slightly sticky

Evaluation: This sample is a mixture of weathered and unweathered material. The unweathered material has excellent expanding characteristics and would make a high quality (excellent) lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	59.1
—1/4 + 1/8	27.2
—1/8 + 16	13.7
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	26.7
—3/8 + 1/4	36.8
—1/4 + 8	16.9
— 8 + 16	8.5
—16 + 35	5.7
—35 + 65	3.5
—65	1.9
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1995	2045
Optimum	2000	2030
Maximum	2010	2090

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	95
Fired	57
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular & Rounded
Pore structure	Coarse, Fine
Expansion	Good
Uniformity of firing	NU

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.39	86.6	14.8
—1/2 + 1/4	1.40	87.2	14.1
—1/4 + 8 mesh	1.31	81.6	9.5

Screen analysis

Size	*Percent retained*
+3/8	24.9
—3/8 + 1/4	54.7
—1/4 + 8	16.7
— 8 + 16	2.5
—16 + 35	.6
—35 + 65	.3
—65	.3
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.92
LB/Ft^3	119
Compression (PSI)	3877
Color (colorimeter)	25
Cure	Autoclave
% Abs.	8.9

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.60
Lb/Ft^3	100
Compression (PSI)	3812
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	7.8

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.92	Bulk Sp. Gr.	1.67
Lb/Ft^3	119	Lb/Ft^3	104
Compression (PSI)	3922	Compression (PSI)	5284
Color (colorimeter)	40	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	9.4	% Abs.	8.1

Potential Uses: Brick, tile and good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated the unweathered material would make an excellent lightweight aggregate. Subsequent rotary kiln tests on a bulk sample indicated that this material would only make a good lightweight aggregate.

CUMBERLAND COUNTY

Sample Number

128-2-1

Quadrangle Newville 15'; Newville 7½'

Location: Exposure along the Pennsylvania Turnpike about 0.25 mile east of the Newville Maintenance Building.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Medium-gray, thin-bedded, relatively unweathered shale which breaks down into pencil-shaped fragments, usually measuring less than 6 inches in their long dimension. Brown iron-staining is common along fracture planes. The exposure extends for a distance of 400 to 500 feet on both sides of the Turnpike and is up to 15-20 feet in height. The overburden is estimated to average less than six inches in thickness.

Attitude of Bedding: NE-SW: 79 NW

Sampled Interval: Grab sample collected from entire exposure along the north side of the Turnpike.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.30
Al_2O_3	15.50
Fe_2O_3	3.70
FeO	3.36
CaO	.98
MgO	2.01
K_2O	3.92
Na_2O	1.30
TiO_2	.82
L.O.I.	6.03
S	.33
CO_2	.26
comb. H_2O	5.45
H_2O @ 120°C	.32

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	32	8
Kaolinite	14	8
C-V-Mo	3	3
Feldspar	3	3

Remarks: some vermiculite (V), talc, and carbonates present

Other Tests:

pH: 8.1
Workability: not plastic, short, gritty
Water of plasticity %: 18.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.5	14.2	2.65
1900	Brown	Soft, crumbly	5.5	16.4	2.63
2000	Med. brown	Very hard	5.5	10.9	2.59
2100	Dk. brown	Steel hard	Exp.	7.3	2.26
2200	Melting and expanding				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1800	1.89	117.7	5.4	No bloating
1900	1.34	83.5	7.3	Slight bloating
2000	0.81	50.5	7.7	Excellent bloating
2100	0.53	33.0	11.4	Excellent bloating
2200	0.30	18.7	27.5	Overbloated, melting, sticky, fragile

Evaluation: Excellent. The shale bloats uniformly and has a long bloating range. The expanded aggregate has low absorption and good strength.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Fair
Particle shape	Elongated
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	64.9
—1/4 + 1/8	27.6
—1/8 + 16	7.5
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	28.5
—3/8 + 1/4	44.7
—1/4 + 8	19.1
— 8 + 16	5.1
—16 + 35	1.3
—35 + 65	.5
—65	.8
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1880	1930
Optimum	1880	1950
Maximum	1960	2040

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	87
Fired	49
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular & Elongated
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.43	89.1	10.0
—1/2 + 1/4	1.39	86.6	8.9
—1/4 + 8 mesh	1.49	92.8	8.2

Screen analysis

Size	*Percent retained*
+3/8	25.3
—3/8 + 1/4	53.6
—1/4 + 8	17.0
— 8 + 16	3.3
—16 + 35	.4
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft^3	92
Compression (PSI)	5698
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.3

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.46
Lb/Ft^3	91
Compression (PSI)	3877
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	6.2

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.62	Bulk Sp. Gr.	1.51
Lb/Ft^3	102	Lb/Ft^3	94
Compression (PSI)	4853	Compression (PSI)	2731
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	4.4	% Abs.	5.5

Potential Uses: Good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated the material would make an excellent lightweight aggregate; however, the results of subsequent rotary kiln tests indicated it should be downgraded to good lightweight aggregate.

CUMBERLAND COUNTY

Sample Number

138-1-1

Quadrangle: Carlisle 15'; Carlisle 7½'

Location: Quarry about 2.9 miles north of Carlisle on the north side of Conodoguinet Creek. The quarried shale is being used for sanitary land fill by the Borough of Carlisle.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Thin-bedded, light- to medium-gray shale is exposed in a quarry which is about 600 feet x 800 feet in plan and averages about 10 feet in height. Locally the shale weathers to a yellow-tan color along fracture and cleavage surfaces.

Attitude of Cleavage: N60E; 45SE

Sampled Interval: Grab sample representing about 300 stratigraphic feet.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	63.50
Al_2O_3	14.90
Fe_2O_3	4.53
FeO	2.72
CaO	.42
MgO	1.91
K_2O	3.98
Na_2O	1.44
TiO_2	.86
L.O.I.	5.74
S	.032
CO_2	1.10
comb. H_2O	3.84
H_2O @ 120°C	.80

Mineralogy: X-ray:

	%	*Accuracy (±)*
Quartz	37	6
Mica	40	8
Kaolinite	6	4
C-V-Mo	4	3
Feldspar	2	2

Remarks: some vermiculite (V) and carbonates present

Other Tests:

pH: 7.0
Workability: not plastic, short
Water of plasticity %: 19.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	4.0	14.5	2.65
1900	Brown	Very hard	5.0	13.0	2.64
2000	Brown red	Steel hard	7.0	8.8	2.60
2100	Dk. brown	Steel hard	7.5	2.3	2.27
2200	Expanding and melting				

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.77	110.2	9.2	No bloating
1900	1.81	112.8	5.2	No bloating
2000	1.45	90.3	5.0	Fair expansion
2100	0.70	43.6	5.3	Excellent bloating
2200	0.73	45.5	4.5	Excellent bloating, slightly sticky

Evaluation: Excellent. This shale has a good bloating range and expands uniformly.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Unweathered

Sizes used in rotary kiln

Size	*Percent retained*
—⅜ + ¼	58.5
—¼ + ⅛	25.9
—⅛ + 16	15.6
Total	100.0

Screen analysis

Size	*Percent retained*
+⅜	27.2
—⅜ + ¼	34.6
—¼ + 8	15.4
— 8 + 16	9.2
—16 + 35	6.4
—35 + 65	3.1
—65	4.1
Total	100.0

Fired Material

Kiln wall & particle temp, °F

	K.W.	*Part.*
Minimum	1890	1940
Optimum	1900	1920
Maximum	2060	2140

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	105
Fired	46
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular, Rounded & Platy
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—¾ + ½	0.96	59.81	4.92
—½ + ¼	1.27	79.12	6.85
—¼ + 8 mesh	1.29	80.37	5.89

Screen analysis

Size	*Percent retained*
+⅜	28.4
—⅜ + ¼	51.2
—¼ + 8	15.4
— 8 + 16	3.1
—16 + 35	1.1
—35 + 65	.4
—65	.4
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.77
Lb/Ft^3	110
Compression (PSI)	2487
Color (colorimeter)	31
Cure	Autoclave
% Abs.	5.7

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.34
Lb/Ft^3	84
Compression (PSI)	1427
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	3.7

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.79	Bulk Sp. Gr.	1.49
Lb/Ft^3	112	Lb/Ft^3	93
Compression (PSI)	3101	Compression (PSI)	2389
Color (colorimeter)	40	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	6.1	% Abs.	5.2

Potential Uses: Brick, tile, and good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated this material would make an excellent lightweight aggregate; however, the results of rotary kiln tests on a bulk sample downgraded its classification to good lightweight aggregate.

CUMBERLAND COUNTY

Sample Number

138-7-2

Quadrangle: Carlisle 15'; Mount Holly Springs 7½'

Location: Philadelphia Clay Company quarry about 3.5 miles south-southwest of Mount Holly Springs on the north side of Mountain Creek.

Geologic Unit: Harpers Formation, Cambrian Age

Description: Varicolored (white, cream, yellow, and some purple) residual clays probably formed from deep weathering of thin-bedded quartzites and phyllites. The sample was collected from "waste clay" that occurs southeast of the white clays which are being quarried for use as a Portland cement whitener. The extent of the exposure of "waste clays" is about 500 feet and is in a direction normal to the strike of the beds in this locality.

Attitude of Bedding: NE-SW; 65 SE

Sampled Interval: Grab sample representing entire exposure of "waste clay."

Type of Material: clay

Chemical Analysis:

	%
SiO_2	67.90
Al_2O_3	19.35
Fe_2O_3	1.90
FeO	.40
CaO	.10
MgO	.77
K_2O	1.90
Na_2O	.11
TiO_2	.97
L.O.I.	6.56
S	.01
CO_2	.18
comb. H_2O	6.25
H_2O @ 120°C	.13

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	55	6
Mica	24	7
Kaolinite	20	8
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 5.9
Workability: fairly plastic and smooth, slightly gritty
Water of plasticity %: 32.0
% Drying shrinkage: 4.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. yel. brown	Soft, crumbly	5.0	27.1	2.61
1900	Lt. yel. brown	Soft, crumbly	5.0	26.8	2.61
2000	Lt. yel. brown	Very hard	5.0	24.7	2.60
2100	Lt. tan brown	Steel hard	10.0	15.6	2.58
2200	Lt. tan gray	Steel hard	15.0	6.5	2.48
2300	Lt. gray tan	Steel hard	22.0	4.0	2.45

Bloating Test: Negative

Potential Uses: Decorative brick and tile.

Remarks: Mottled colors at 2100°F very attractive and unusual.

CUMBERLAND COUNTY

Sample Number

138-7-2A

Quadrangle: Carlisle 15'; Mount Holly Springs 7½'

Location: Philadelphia Clay Company quarry about 3.5 miles south-southwest of Mount Holly Springs on the north side of Mountain Creek.

Geologic Unit: Harpers Formation, Cambrian Age

Description: Varicolored (white, cream, yellow, and some purple) residual clays probably formed from deep weathering of thin-bedded quartzites and phyllites. The sample was collected from "waste clay" that occurs southeast of the white clays which are being quarried for use as a Portland cement whitener. The extent of the exposure of "waste clays" is about 500 feet and is in a direction normal to the strike of the beds in this locality.

Attitude of Bedding: NE-SW; 65 SE

Sampled Interval: Grab sample representing entire exposure of "waste clays."

Type of Material: clay

Chemical Analysis:

	%
SiO_2	68.50
Al_2O_3	19.30
Fe_2O_3	1.70
FeO	.60
CaO	.25
MgO	.68
K_2O	1.59
Na_2O	.08
TiO_2	1.00
L.O.I.	6.27
S	.032
CO_2*	.18
comb. H_2O	6.01
H_2O @ 120°C	.05

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	38	12
Mica	21	6
Kaolinite	40	12
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 5.5
Workability: fairly plastic, smooth, gritty
Water of plasticity %: 34.0
% Drying shrinkage: 1.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	2.0	31.4	2.62
1900					
2000	Lt. pink buff	Soft, crumbly	4.5	28.9	2.62
2100	Lt. pink buff	Very hard	10.0	18.7	2.61
2200	Lt. gray tan	Steel hard	13.5	13.6	2.63
2300	Lt. gray	Steel hard	16.0	5.2	2.47
2400	Lt. gray	Steel hard	16.0	4.1	2.44

Bloating Test: Negative

Pyrometric cone equivalent: 20 **Cone color:** Light gray, black speckled.

Potential Uses: Low-duty refractories, decorative brick and tile.

Remarks: Mottled colors, fairly attractive.

DAUPHIN COUNTY

Sample Number

146-7-1

Quadrangle: Millersburg 15'; Millersburg 7½'

Location: Outcrop about 0.3 mile north of the town of Millersburg on the east side of the roadway which trends generally north-south and passes the east side of the cemetery in Millersburg.

Geologic Unit: Mauch Chunk Formation, Mississippian Age

Description: Grayish-red shales with some interbedded siltstones outcrop along the roadway for a distance of about 500 feet. The outcrop is up to 20 feet high in places. Its overburden averages from one to two feet thick.

Attitude of Bedding: N65E; 35S

Sampled Interval: Channel sample of the upper 20 stratigraphic feet.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.00
Al_2O_3	17.00
Fe_2O_3	6.48
FeO	1.23
CaO	.12
MgO	1.21
K_2O	3.98
Na_2O	.60
TiO_2	.98
L.O.I.	4.33
S	.006
CO_2	.18
comb. H_2O	4.25

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	43	8
Mica	41	10
Kaolinite	1	2
C-V-Mo	4	4
Feldspar	1	2

Other Tests:

pH: 6.5
Workability: short working, mealy, fairly smooth
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	1.5	17.6	2.71
1900	Dk. buff brown	Soft, crumbly	1.5	15.8	2.69
2000	Med. brown	Fairly hard	3.0	13.3	2.67
2100	Dk. brown	Hard	5.0	9.9	2.63
2200	Dk. brown	Very hard	6.5	5.8	2.45
2300	Gray black	Steel hard	Exp.	8.1	2.23

Bloating Test: Negative

Potential Uses: Possibly brick.

DAUPHIN COUNTY

Sample Number

148-3-1

Quadrangle: New Cumberland 15'

Location: Exposure located approximately 0.3 mile east of Oberlin and about 200 feet west of U. S. Route 230 (Bypass).

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Grayish-orange, weathered shale is exposed in a cut about ten feet high which extends for a distance of several hundred feet along the roadway. A soil overburden, about one foot thick, overlies the shale.

Sampled Interval: Channel sample from one to ten feet vertically below the surface

Type of Material: shale

Chemical Analysis:

	%
SiO_2	68.40
Al_2O_2	14.00
Fe_2O_3	6.55
FeO	.77
CaO	.07
MgO	.98
K_2O	3.22
Na_2O	.18
TiO_2	.74
L.O.I.	5.06
S	.012
CO_2	.26
comb. H_2O	4.80

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	44	8
Mica	44	10
Kaolinite	1	3
C-V-Mo	6	4
Feldspar	0	2

Other Tests:

pH: 6.4
Workability: slightly plastic, short working, fairly smooth, fatty
Water of plasticity %: 19.0
% Drying shrinkage: 0.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	0.5	28.5	2.72
1900	Dk. buff brown	Soft, crumbly	0.5	25.4	2.73
2000	Brown	Fairly hard	1.5	22.8	2.71
2100	Med. brown	Hard	3.0	17.7	2.66
2200	Dk. brown	Very hard	4.0	11.4	2.53
2300	Gray black	Steel hard	5.0	7.6	2.25

Bloating Test: Negative

Potential Uses: Possibly brick.

ERIE COUNTY

Sample Number

1-5-1

Quadrangle: Girard 15'; East Springfield 7½'

Location: Exposure located about 1.9 miles west of Albion on the north side of State Route 179 and west of Conneaut Creek.

Geologic Unit: Pleistocene glacial lake deposit, Quaternary Age

Description: The exposure consists of a very-light-gray clay which is believed to be a glacial lake deposit that formed when a terminal moraine dammed up the north-flowing Conneaut Creek. The areal extent of the clay is estimated to be about 40 million square feet and its thickness is estimated to average 10 feet.

Sampled Interval: Grab sample from a radius of several hundred feet

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.30
Al_2O_3	17.00
Fe_2O_3	2.57
FeO	3.48
CaO	2.45
MgO	1.71
K_2O	4.00
Na_2O	.75
TiO_2	.86
L.O.I.	7.80
S	.66
CO_2	4.47
comb. H_2O	2.71
H_2O @ 120°C	.62

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	8
Mica	37	8
Kaolinite	14	8
C-V-Mo	5	3
Feldspar	1	2

Other Tests:

pH: 7.7
Workability: smooth and plastic, slightly fatty
Water of plasticity %: 30.0
% Drying shrinkage: 6.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Sandy brown	Soft, crumbly	7.5	17.8	2.54
1900	Sandy brown	Soft, crumbly	9.0	16.1	2.53
2000	Sandy brown	Very hard	10.5	8.3	2.45
2100	Brown	Steel hard	15.5	0.9	2.38
2200	Melting and expanding				

Bloating Test: Slight expansion

Potential Uses: Possibly sintered aggregate.

Remarks: Slight effervescence and scummy—indicates calcium sulfate or carbonate.

FAYETTE COUNTY

Sample Number

49-4-1A

Quadrangle: Confluence 15'

Location: Quarry operation about 2.25 miles south of Ohiopyle.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: A soft, medium-gray clay, three feet thick, lies directly below the lowermost of three benches which represent the Lower Kittanning coal. The quarry workings are extensive and its high wall exceeds a height of 75 feet in places.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample from 0-3 feet vertically below the Lower Kittanning coal

Type of Material: clay

Chemical Analysis:

	%
SiO_2	45.20
Al_2O_3	34.20
Fe_2O_3	1.85
FeO	1.00
CaO	.13
MgO	.47
K_2O	1.97
Na_2O	.42
TiO_2	1.55
L.O.I.	13.18
S	.62
CO_2	1.98
comb. H_2O	11.20

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	15	8
Mica	13	6
Kaolinite	57	15
C-V-Mo	5	3
Feldspar	2	3

Other Tests:

pH: 3.5
Workability: fairly plastic and smooth
Water of plasticity %: 19.0
% Drying shrinkage: 2.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. buff	Soft, crumbly	4.0	17.3	2.74
1900	Lt. buff	Hard	7.0	14.2	2.73
2000	Lt. buff	Very hard	8.0	9.9	2.69
2100	Lt. tan buff	Steel hard	10.0	6.6	2.68
2200	Lt. red	Steel hard	12.0	4.5	2.64
2300	Lt. red gray	Steel hard	12.0	4.7	2.61

Bloating Test: Negative

Pyrometric cone equivalent 32-33 **Cone color:** Light gray with black specks

Potential Uses: Decorative brick, tile, chimney flue tile, drain tile, high-duty refractories.

Remarks: Excellent brick and tile properties.

FAYETTE COUNTY

Sample Number

49-4-1B

Quadrangle: Confluence 15'

Location: Quarry operation about 2.25 miles south of Ohiopyle.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: A mottled brown and dark-gray flint clay, 4 feet thick, underlies a 3-foot soft clay beneath the lowest bench of the Lower Kittanning coal. The flint clay weathers to a light-gray color.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample from 3 to 7 feet vertically below the lowest bench of Lower Kittanning coal.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	45.50
Al_2O_3	36.40
Fe_2O_3	.60
FeO	.40
CaO	.06
MgO	.09
K_2O	.11
Na_2O	.23
TiO_2	1.80
L.O.I.	14.78
S	.43
CO_2	2.02
comb. H_2O	12.54
H_2O @ 120°C	.30

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	15	8
Mica	17	8
Kaolinite	61	15
C-V-Mo	4	3
Feldspar	1	3

Remarks: some limonite present

Other Tests:

pH: 4.5
Workability: not plastic, very gritty, very short
Water of plasticity %: 16.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Specimen too crumbly to determine properties. Fired colors range from light buff to light gray		1800-2400.		

Pyrometric cone equivalent: 34 **Cone color:** Light gray

Potential Uses: Super-duty refractories products.

FRANKLIN COUNTY

Sample Number

108-6-1

Quadrangle: Orbisonia 15'

Location: Exposure along the Pennsylvania Turnpike about 4 miles northeast of the east portal of the tunnel through Tuscarora Mountain and about 1.50 miles south of the town of Spring Run.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The exposure consists of medium-gray, interbedded shales and siltstones which weather to colors of very pale orange, gray orange, and dark yellowish orange. The shale is thin-bedded and breaks into platy fragments whereas the siltstone beds range up to 4 or 5 inches in thickness and break into irregular tabular fragments. The siltstone beds are more common in the middle part of the exposure. The exposure extends for a distance of about 800 feet along the Turnpike. The overburden is estimated to be less than six inches thick.

Attitude of Bedding: NE-SW; 45 SE

Sampled Interval: Grab sample taken from the western 400 feet of the exposure along the south side of the Turnpike.

Type of Material: shale

Chemical Analysis:

SiO_2	
Al_2O_3	no
Fe_2O_3	
FeO	chemical
CaO	
MgO	analysis
K_2O	
Na_2O	
TiO_2	
L.O.I.	
S	
CO_2	
comb. H_2O	
H_2O @ 120°C	

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	35	8
Kaolinite	4	3
C-V-Mo	5	3
Feldspar	4	3

Remarks: some calcite present

Other Tests:

pH: 6.9
Workability: not plastic, short, gritty, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 3.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff brown	Soft, crumbly	2.5	20.7	2.68
1900	Brown	Soft, crumbly	1.5	17.8	2.65
2000	Brown	Very hard	5.0	15.5	2.59
2100	Dk. brown	Steel hard	5.0	10.3	1.84
2200	Very dk. brown	Steel hard	Exp.	12.2	1.36
2300	Melted and expanded				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.60	99.7	7.4	No bloating
2000	1.08	67.3	8.8	Good bloating
2100	1.02	63.5	11.8	Excellent bloating
2200	0.70	43.6	33.1	Overbloated, melting and sticky

Evaluation: An examination of the fired material indicates that the sample is a mixture of weathered and unweathered shale. The unweathered material has fair to good aggregate possibilities.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	44.4
—1/4 + 1/8	33.5
—1/8 + 16	22.1
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	15.3
—3/8 + 1/4	28.3
—1/4 + 8	21.4
— 8 + 16	14.2
—16 + 35	10.3
—35 + 65	5.8
—65	4.7
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1890	1940
Optimum	1920	1950
Maximum	1950	2030

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	98
Fired	55
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular, Elongated & Platy
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.³*	*% Abs.*
—3/4 + 1/2	1.63	101.6	10.2
—1/2 + 1/4	1.63	101.6	10.5
—1/4 + 8 mesh	1.31	81.6	4.9

Screen analysis

Size	*Percent retained*
+3/8	34.2
—3/8 + 1/4	44.9
—1/4 + 8	17.3
— 8 + 16	2.8
—16 + 35	.4
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.62
Lb/Ft³	101
Compression (PSI)	4089
Color (colorimeter)	37
Cure	Autoclave
% Abs.	6.2

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.45
Lb/Ft³	90
Compression (PSI)	5121
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	2.9

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.68	Bulk Sp. Gr.	1.66
Lb/Ft^3	104	Lb/Ft^3	104
Compression (PSI)	4572	Compression (PSI)	2959
Color (colorimeter)	38	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	7.9	% Abs.	6.6

Potential Uses: Good lightweight aggregate.

FULTON COUNTY

Sample Number

98-9-1

Quadrangle: Broad Top 15'

Location: Exposure along the south side of the Pennsylvania Turnpike, about 3.2 miles east of the east portal of the Sideling Hill tunnel and about 1.7 miles west of Hustontown.

Geologic Unit: Catskill Formation, Devonian Age

Description: Pale-red and grayish-red, thin-bedded shales, siltstones and sandstones in the lower part of the Catskill Formation extend for a distance of about 850 feet along the south side of the Turnpike. The sandstones and siltstones are the thickest beds, ranging up to 6 inches in some cases. They are more common in the western part of the exposure. A thin soil overburden, estimated to be one-foot thick, occurs at the top of the roadcut.

Attitude of Bedding: NE-SW; 34NW

Sampled Interval: Grab sample from 500 feet of exposed section

Type of Material: shales, siltstones and sandstones

Chemical Analysis:

	%
SiO_2	71.90
Al_2O_3	13.05
Fe_2O_3	4.84
FeO	.91
CaO	.20
MgO	.82
K_2O	3.10
Na_2O	.90
TiO_2	.89
L.O.I.	3.34
S	.019
CO_2*	.31
comb. H_2O	2.57
H_2O @ 120°C	.44

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	51	10
Mica	34	8
Kaolinite	0	2
C-V-Mo	2	2
Feldspar	3	3

Other Tests:

pH: 6.9
Workability: not plastic, short, gritty, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Brown	Soft, crumbly	1.5	16.0	2.54
1900	Brown	Soft, crumbly	4.5	15.1	2.57
2000	Brown	Fairly hard	4.5	15.4	2.56
2100	Dk. brown	Hard	4.5	13.3	2.54
2200	Very dk. brown	Hard	5.5	11.4	2.49
2300	Very dk. brown	Steel hard	5.5	10.3	2.48

Bloating Test: Negative

Potential Uses: None.

HUNTINGDON COUNTY

Sample Number

96-9-1

Quadrangle: Tyrone 15'

Location: Quarry operated by the Alexandria Fire Clay Company about 3 miles southeast of Alexandria along the Old Philadelphia Pike.

Geologic Unit: Oriskany Formation, Devonian Age

Description: The quarried material consists of a white siliceous clay which is a weathered product of the Oriskany Formation. The clay is fossiliferous in part and contains some chert and shale fragments. The width of the quarry is about 50 feet, bordered on the west by an Oriskany sandstone which dips steeply to the west. The east wall of the quarry consists of shale.

Sampled Interval: Grab sample from stockpile of quarried clay

Type of Material: clay

Chemical Analysis:

	%
SiO_2	91.05
Al_2O_3	5.00
Fe_2O_3	.21
FeO	.76
CaO	.05
MgO	.15
K_2O	.91
Na_2O	.08
TiO_2	.30
L.O.I.	1.44
S	.10
CO_2*	.67
comb. H_2O	.56
H_2O @ 120° C	.11

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	85	12
Mica	10	5
Kaolinite	0	2
C-V-Mo	2	2
Feldspar	1	2

Remarks: some calcite present

Other Tests:

pH: 6.4
Workability: fairly plastic, short, gritty
Water of plasticity %: 28.0
% Drying shrinkage: 2.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	4.0	Crumbled	2.47
1900	Very lt. brown	Soft, crumbly	4.5	24.1	2.46
2000	Lt. gray	Soft, crumbly	4.5	24.0	2.45
2100	Lt. gray	Soft, crumbly	4.5	23.2	2.45
2200	Lt. gray	Very hard	4.5	20.2	2.43
2300	Lt. gray	Very hard	6.0	17.9	2.44

Pyrometric cone equivalent: 23-26 **Cone color:** Gray

Potential Uses: Low-duty refractory products; refractory mortar.

HUNTINGDON COUNTY

Sample Number

97-3-1

Quadrangle: Huntingdon 15'

Location: Exposure about 0.4 mile southwest of Huntingdon on the north side of U. S. Route 22 about 0.25 mile northwest of the overpass to the Huntingdon and Broadtop Mountain R. R.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: Medium- to medium-dark-gray, predominantly thick-bedded, massive-looking shales occur from 200 to 500 feet from the western edge of this exposure along the north side of U. S. Route 22. The beds average 2 to 3 feet in thickness with a few measuring only several inches. Siderite nodules occur at places in this section but are sparse. Weathered fragments on the shope are tabular with very angular edges. The majority of these average from 1 to 2 inches in their long dimension. The rock in the western 200 feet of the exposure is silty and siliceous and was not sampled. The eastern 450 feet of exposed rock contains numerous siderite nodules and for this reason was not sampled.

Attitude of Bedding: N32E; 7SE

Sampled Interval: Grab sample collected from 300 feet of the exposed section, starting 200 feet from the western edge of the exposure and continuing eastward for the next 300 feet

Type of Material: shale

Chemical Analysis:

	%
SiO_2	65.30
Al_2O_3	13.20
Fe_2O_3	1.76
FeO	4.26
CaO	3.11
MgO	1.00
K_2O	2.88
Na_2O	.79
TiO_2	.87
L.O.I.	6.78
S	.28
CO_2*	3.59
comb. H_2O	2.70
H_2O @ 120°C	.21

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	44	8
Mica	29	6
Kaolinite	14	8
C-V-Mo	1	3
Feldspar	1	2

Remarks: some carbonates present

Other Tests:

pH: 9.1
Workability: not plastic, short
Water of plasticity %: 18.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	4.5	19.0	2.62
1900	Brown	Soft, crumbly	4.5	18.9	2.63
2000	Brown	Soft, crumbly	4.5	18.2	2.63
2100	Dk. red brown	Steel hard	5.5	13.0	2.57
2200	Gray black	Steel hard	Exp.	3.9	1.66
2300	Expanded and melting				

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.41	150.1	3.4	No bloating
2000	2.30	143.3	2.9	No bloating
2100	2.19	136.4	1.7	No bloating
2200	1.63	101.5	3.7	Slight expansion

Evaluation: Possibly sintered aggregate.

Potential Uses: Possibly brick, floor tile, and sintered aggregate.

Remarks: Acid treatment shows appreciable quantities of calcareous material.

HUNTINGDON COUNTY

Sample Number

108-8-2

Quadrangle: Orbisonia 15'

Location: Exposure along the north side of the Pennsylvania Turnpike, about 2.2 miles southwest of the west portal of the Tuscarora Mountain tunnel and about 0.7 mile east of the town of Burnt Cabins.

Geologic Unit: Bloomsburg Formation, Silurian Age

Description: The exposure consists of grayish-red shales with some interbeds of yellow shales. The shales are commonly very thin-bedded but in some cases reach a maximum thickness of 4 inches. Fragments broken from the thinner beds are platy and chip-like whereas those broken from the thicker beds are tabular. The exposure extends for a distance of about 600 feet along the Turnpike.

Attitude of Bedding: NE-SW; 57SE

Sampled Interval: Grab sample collected from the western 350 feet of the exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	58.60
Al_2O_3	13.85
Fe_2O_3	5.86
FeO	.72
CaO	5.60
MgO	.95
K_2O	4.40
Na_2O	.40
TiO_2	.80
L.O.I.	8.78
S	.01
CO_2	5.13
comb. H_2O	3.46
H_2O @ 120°C	.19

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	8
Mica	46	8
Kaolinite	0	2
C-V-Mo	2	2
Feldspar	0	2

Remarks: calcite and hematite present

Other Tests:

pH: 8.6
Workability: not plastic, short, hardens on standing
Water of plasticity %: 17.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	1.5	21.5	2.64
1900	Brown	Soft, crumbly	1.5	18.9	2.57
2000	Brown	Soft, crumbly	3.5	18.8	2.61
2100	Dk. brown	Very hard	4.5	15.7	2.57
2200	Very dk. brown	Steel hard	5.5	7.9	2.45
2300	Melting				

Bloating Test: Negative

Potential Uses: Possibly brick.

HUNTINGDON COUNTY

Sample Number

108-8-3

Quadrangle: Orbisonia 15'

Location: Outcrop along the east side of the roadway which passes under the Pennsylvania Turnpike about 2.2 miles southwest of the west portal to the Tuscarora Mountain tunnel. The sampled outcrop is north of the Turnpike.

Geologic Unit: Rose Hill Formation, Clinton Group, Silurian Age

Description: Interbedded greenish-gray shales and siltstones of the upper part of the Rose Hill Formation extend for a distance of about 350 feet along the roadway to the north of the Pennsylvania Turnpike. The siltstone beds are well cemented and difficult to break. The entire section is thin-bedded with the thicker beds—the siltstones—ranging up to 3 or 4 inches in thickness.

Attitude of Bedding: EW; 50N

Sampled Interval: Grab sample form 250 feet of exposure

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	61.00
Al_2O_3	17.70
Fe_2O_3	4.29
FeO	2.89
CaO	1.14
MgO	1.31
K_2O	4.21
Na_2O	.40
TiO_2	.92
L.O.I.	6.11
S	.036
CO_2*	1.84
comb. H_2O	3.69
H_2O @ 120°C	.54

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	40	8
Mica	44	8
Kaolinite	6	4
C-V-Mo	3	2
Feldspar	0	2

Remarks: some carbonate present

Other Tests:

pH: 8.6
Workability: not plastic, short, gritty, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	1.0	15.0	2.64
1900	Brown	Soft, crumbly	4.5	13.6	2.64
2000	Brown	Hard	4.5	12.1	2.63
2100	Dk. brown	Very hard	5.5	9.8	2.61
2200	Very dk. brown	Steel hard	6.0	5.5	2.50
2300	Melting				

Bloating Test: Negative

Potential Uses: Possibly brick.

INDIANA COUNTY

Sample Number

67-1-1

Quadrangle: Johnstown 15′

Location: Exposure on the west side of State Route 711 about 0.2 mile south-southwest of Cramer.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: The exposure consists of a medium-gray underclay beneath the Lower Kittanning coal. The clay is 48 inches thick and is silty in the lowermost foot. Yellow-orange iron oxide staining is common along the fractures. The extent of the exposure is about 400 feet along the road.

Attitude of Bedding: N15E; 4W

Sampled Interval: 4-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	57.65
Al_2O_3	26.50
Fe_2O_3	1.17
FeO	.36
CaO	.05
MgO	.45
K_2O	2.80
Na_2O	.40
TiO_2	1.47
L.O.I.	9.09
S	.042
CO_2	1.46
comb. H_2O	6.29
H_2O @ 120°C	1.34

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	6
Mica	32	6
Kaolinite	18	10
C-V-Mo	1	2
Feldspar	1	2

Other Tests:

pH: 4.3
Workability: fairly plastic and smooth working
Water of plasticity %: 20.0
% Drying shrinkage: 2.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Very lt. pink	Soft, crumbly	3.0	16.4	2.55
1900	Very lt. pink	Soft, crumbly	5.0	14.2	2.59
2000	Very lt. pink	Very hard	7.0	10.8	2.57
2100	Very lt. tan	Steel hard	9.0	7.3	2.55
2200	Lt. tan gray	Steel hard	10.5	3.4	2.48
2300	Lt. gray tan	Steel hard	10.5	5.1	2.47

Pyrometric cone equivalent: 23-26 **Cone color:** Light gray

Potential Uses: Decorative brick, tile, chimney flue tile, low-duty refractories.

JEFFERSON COUNTY

Sample Number

63-9-1

Quadrangle: Hallton 15'

Location: Underground mine about 0.25 mile north-northwest of Brockway Clay Company plant in Brockway.

Geologic Unit: Clarion underclay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium- to medium-light-gray underclay that is reported to be about 10 feet thick was grab sampled from broken rock in the mine cars at the plant site.

Sampled Interval: Grab sample from mine cars

Type of Material: clay

Chemical Analysis:

	%
SiO_2	66.20
Al_2O_3	18.30
Fe_2O_3	1.32
FeO	.99
CaO	.12
MgO	.31
K_2O	1.39
Na_2O	.34
TiO_2	1.36
L.O.I.	9.63
S	.50
CO_2*	5.42
comb. H_2O	3.38
H_2O @ 120°C	.33

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	55	8
Mica	22	8
Kaolinite	14	8
C-V-Mo	2	2
Feldspar	0	2

Remarks: carbonates present

Other Tests:

pH: 7.9
Workability: not plastic, short, gritty
Water of plasticity %: 19.0
% Drying shrinkage: 4.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Very lt. brown	Soft, crumbly	5.0	17.7	2.48
1900	Very lt. brown	Soft, crumbly	5.0	16.9	2.48
2000	Very lt. brown	Soft, crumbly	5.0	16.1	2.48
2100	Lt. brown	Hard	5.0	17.2	2.56
2200	Lt. brown	Very hard	6.0	12.1	2.44
2300	Lt. brown gray	Very hard	6.0	7.5	2.36

Bloating Test: Negative

Potential Uses: Sewer pipe.

JEFFERSON COUNTY

Sample Number

64-3-1

Quadrangle: DuBois 15'

Location: Brockway Clay Company quarry about 3.5 miles southeast of Brockway. The quarry is located on the east side of a ridge about 0.25 mile south of McEwen Run and about a mile east of the Buffalo, Rochester and Pittsburgh Railroad tracks.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Medium- to medium-light-gray underclay to the Lower Kittanning (?) coal is exposed in the quarry. The clay is eight feet thick. Its top occurs about 50 feet below the surface of the ridge.

Sampled Interval: 8-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	60.80
Al_2O_3	24.55
Fe_2O_3	1.71
FeO	.46
CaO	.12
MgO	.45
K_2O	2.30
Na_2O	.25
TiO_2	1.34
L.O.I.	8.00
S	.29
CO_2*	5.95
comb. H_2O	.90
H_2O @ 120°C	.86

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	41	10
Mica	39	10
Kaolinite	10	8
C-V-Mo	1	3
Feldspar	0	3

Other Tests:

pH: 7.3
Workability: fairly plastic and smooth
Water of plasticity %: 31.0
% Drying shrinkage: 4.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Very lt. buff	Soft, crumbly	5.5	15.9	2.58
1900	Very lt. buff	Soft, crumbly	5.5	16.3	2.62
2000	Lt. buff	Hard	8.0	13.4	2.59
2100	Lt. tan	Steel hard	9.5	9.7	2.58
2200	Tan	Steel hard	9.5	6.4	2.53
2300	Tan gray	Steel hard	13.0	1.4	2.38

Bloating Test: Negative

Pyrometric cone equivalent: 23 **Cone color:** Gray

Potential Uses: Brick, tile; possibly low-duty refractory products such as ladle brick.

JUNIATA COUNTY

Sample Number

126-8-1

Quadrangle: Mifflintown 15'; Mifflintown 7½'

Location: Quarry located about one mile south of Port Royal and about 0.2 mile south-southeast of Old Port School along the east side of Blue Spring Hollow Road.

Geologic Unit: Marcellus Formation, Hamilton Group, Devonian Age

Description: Brownish-black to dark-gray, fissile shale is exposed in a quarry which extends for a distance of about 100 feet along the road. The walls of the quarry are about 30 feet high. Yellow-orange and brown iron-oxide stains commonly occur along joint and bedding planes. Deposits of a white sulphate precipitate occur locally. The overburden is from two to three feet deep.

Attitude of Bedding: N68E; 32NW

Sampled Interval: Grab sample from lower 50 stratigraphic feet of exposed rock

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.80
Al_2O_3	14.70
Fe_2O_3	4.99
FeO	1.37
CaO	1.94
MgO	.95
K_2O	3.43
Na_2O	.58
TiO_2	.71
L.O.I.	6.50
S	1.41
CO_2*	3.55
comb. H_2O	.84
H_2O @ 120°C	.60

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	45	6
Mica	39	8
Kaolinite	5	3
C-V-Mo	2	2
Feldspar	1	2

Remarks: calcite present

Other Tests:

pH: 6.75
Workability: slightly plastic, short, hardens on standing
Water of plasticity %: 19.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Brown	Soft, crumbly	2.5	18.0	2.40
1900	Brown	Soft, crumbly	5.0	15.5	2.34
2000	Brown	Very hard	5.5	11.5	2.31
2100	Brown	Steel hard	9.0	2.0	1.99
2200	Melting				

Bloating Test: Negative

Potential Uses: None.

JUNIATA COUNTY

Sample Number

126-8-3

Quadrangle: Mifflintown 15'; Mifflintown 7½'

Location: Exposure in a road cut along the east side of U. S. Highway Route 322 about 0.4 mile north of the center of Mifflintown.

Geologic Unit: Bloomsburg Formation, Silurian Age

Description: Interbedded red shales and siltstones with beds ranging from ¼ inch up to 32 inches in thickness are exposed in a roadcut. The siltstone beds are usually thicker than the shales. One siltstone bed which is two feet thick contains numerous hard, siliceous nodules. The rocks break into irregular fragments. The exposure extends for a distance of more than 200 feet along the road and is about 15 feet high. The overburden is from 0 to several inches thick.

Attitude of Bedding: N60E; 34S

Sampled Interval: Grab sampled for a distance of 180 feet along road

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	63.30
Al_2O_3	14.00
Fe_2O_3	5.47
FeO	1.39
CaO	3.77
MgO	1.00
K_2O	3.03
Na_2O	.46
TiO_2	.86
L.O.I.	6.73
S	.020
CO_2*	3.37
comb. H_2O	3.10
H_2O @ 120°C	.24

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	51	8
Mica	37	8
Kaolinite	0	2
C-V-Mo	3	2
Feldspar	1	3

Remarks: some calcite present

Other Tests:

pH: 9.1
Workability: not plastic, short, slightly gritty, hardens on standing
Water of plasticity %: 15.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Brown	Soft, crumbly	1.0	13.7	2.43
1900	Brown	Soft, crumbly	1.0	13.1	2.40
2000	Brown	Hard	1.5	11.8	2.36
2100	Dk. brown	Very hard	4.0	5.2	2.30
2200	Melted				

Bloating Test: Negative

Potential Uses: None

LANCASTER COUNTY

Sample Number

158-6-1

Quadrangle: Middletown 15'

Location: Exposure about 3.0 miles south of Mastersonville (Lancaster quadrangle) along the east side of the medium-duty road trending south from that town.

Geologic Unit: Cocalico Formation, Ordovician Age

Description: Grayish-orange to reddish-brown clay which contains fragments of dark-gray shale is exposed for a distance of about 500 feet along the road. Relict structure indicates bedding is generally horizontal. The exposure is about 10 feet high with the upper 2 feet consisting of soil overburden.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample from 2 to 10 feet vertically below the surface

Type of Material: clay and shale

Chemical Analysis:

	%
SiO_2	62.00
Al_2O_3	15.70
Fe_2O_3	5.68
FeO	1.77
CaO	.04
MgO	1.58
K_2O	3.77
Na_2O	.57
TiO_2	.93
L.O.I.	7.92
S	.010
CO_2	.66
comb. H_2O	7.26

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	36	8
Kaolinite	8	6
C-V-Mo	5	4
Feldspar	1	2

Remarks: little or no chlorite (C) present

Other Tests:

pH: 5.0
Workability: not plastic, very short and gritty
Water of plasticity %: 20.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Orange buff	Soft, crumbly	1.5	19.6	2.56
1900	Orange buff	Soft, crumbly	1.5	18.7	2.58
2000	Orange buff	Soft, crumbly	5.0	15.6	2.52
2100	Orange brown	Very hard	5.0	12.0	2.45
2200	Brown	Steel hard	6.0	5.7	2.39
2300	Dk. brown	Steel hard	9.0	2.7	2.25

Potential Uses: None

LANCASTER COUNTY

Sample Number

168-2-4

Quadrangle: Lancaster 15'; Lititz 7½'

Location: Glen Gery Shale Brick Corporation quarry located about 3 miles west of Brickerville.

Geologic Unit: New Oxford Formation, Triassic Age

Description: Dark-reddish-brown clay, nine feet thick, overlies gray-red shales of the New Oxford Formation. The clay is a weathered product of these shales. Green and yellow-green shales are interbedded with some sandstone beds in parts of the quarry but these were not sampled.

Attitude of Bedding: N75E; 50N

Sampled Interval: Channel sample taken from 2 to 12 feet vertically below the surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	63.10
Al_2O_3	16.30
Fe_2O_3	7.84
FeO	.20
CaO	.40
MgO	1.54
K_2O	2.44
Na_2O	.30
TiO_2	.83
L.O.I.	7.00
S	.006
CO_2	.26
comb. H_2O	5.89
H_2O @ 120°C	.85

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	45	8
Mica	37	6
Kaolinite	5	4
C-V-Mo	6	4
Feldspar	0	2

Other Tests:

pH: 4.95
Workability: plastic and smooth, fine grit
Water of plasticity %: 24.0
% Drying shrinkage: 5.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. brown	Fairly hard	6.5	16.3	2.63
1900	Lt. brown	Fairly hard	9.5	14.9	2.61
2000	Lt. brown	Very hard	9.5	16.1	2.60
2100	Brown (rich)	Steel hard	10.5	7.9	2.57
2200	Dk. brown	Steel hard	11.0	5.8	2.53
2300	Dk. brown	Steel hard	13.5	2.5	2.46

Bloating Test: Negative

Potential Uses: Brick and floor tile.

LANCASTER COUNTY

Sample Number

168-3-1

Quadrangle: Lancaster 15'; Lititz 7½'

Location: Exposure about 3.5 miles north of Lititz on the north side of the road connecting Penn and Clay.

Geologic Unit: Cocalico Formation, Ordovician Age

Description: The exposure consists of medium-gray Cocalico shales which can be seen for a distance of about 30 feet up the slope. Some of the more weathered shale is gray-yellow in color.

Attitude of Bedding: NE-SW; moderate dip to NW.

Sampled Interval: Twenty stratigraphic feet were channel sampled, starting 8 feet from the base of the exposure and working upslope.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.00
Al_2O_3	16.50
Fe_2O_3	4.23
FeO	3.22
CaO	.14
MgO	2.03
K_2O	3.99
Na_2O	1.35
TiO_2	.90
L.O.I.	6.60
S	.012
CO_2	.95
comb. H_2O	5.65

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	33	7
Kaolinite	14	8
C-V-Mo	17	8
Feldspar	2	2

Other Tests:

pH: 5.1
Workability: not plastic, very short, crumbly
Water of plasticity %: 20.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. brown	Soft, crumbly	1.0	21.4	2.65
1900	Lt. brown	Soft, crumbly	1.0	18.7	2.64
2000	Lt. brown	Fairly hard	3.0	16.1	2.62
2100	Brown	Hard	4.5	14.6	2.60
2200	Dk. brown	Very hard	5.0	10.3	2.55
2300	Very dk. brown	Steel hard	Exp.	5.0	2.31

Bloating Test: Negative

Potential Uses: None

LANCASTER COUNTY

Sample Number

168-3-2

Quadrangle: Lancaster 15'; Lititz 7½'

Location: Property located about one mile north of Lititz, northeast of the intersection of State Route 501 and the northwest trending road between Halfville and Rothsville.

Geologic Unit: Cocalico Formation, Ordovician Age

Description: An exposure of weathered yellow-brown shale, about 20 feet in height, extends for a distance of several hundred feet along the roadway. Two feet of soil overburden overlie the exposed shale.

Attitude of Cleavage: N50E; 47NW

Sampled Interval: Channel sample taken from 2 to 17 feet vertically beneath the surface

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.90
Al_2O_3	16.60
Fe_2O_3	5.50
FeO	2.07
CaO	.07
MgO	1.87
K_2O	3.78
Na_2O	.79
TiO_2	.86
L.O.I.	5.54
S	.010
CO_2	.33
comb. H_2O	5.21

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	34	6
Mica	35	8
Kaolinite	0	2
C-V-Mo	24	8
Feldspar	1	2

Remarks: carbonates present

Other Tests:

pH: 5.1
Workability: not plastic, very short and gritty
Water of plasticity %: 26.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. brown buff	Soft, crumbly	1.5	28.6	2.62
1900	Lt. brown buff	Soft, crumbly	1.5	27.6	2.60
2000	Lt. brown buff	Soft, crumbly	1.5	25.5	2.62
2100	Brown	Fairly hard	4.0	21.9	2.60
2200	Dk. brown	Very hard	6.0	13.4	2.54
2300	Dk. brown	Steel hard	10.0	6.1	2.44

Bloating Test: Negative

Potential Uses: None

LANCASTER COUNTY

Sample Number

168-8-3

Quadrangle: Lancaster 15'; Lancaster 7½'

Location: Quarry owned by the Lancaster Brick Company about 1.5 miles northwest of the city of Lancaster and about 250 feet east of the Lancaster Brick Company Office.

Geologic Unit: Conestoga Formation, Ordovician Age

Description: The quarry is in a residual clay formed by the weathering of Conestoga limestone. The depth of clay ranges from two to 15 feet, being thinnest where limestone "pinnacles" occur. The prevailing colors of the clay are yellow-orange and yellow-brown, but near the contact with the underlying limestone bedrock, the clay is olive-gray.

Attitude of Bedding: N85W; 55S

Sampled Interval: Channel sample taken from 1½ to 11 feet below surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	62.40
Al_2O_3	16.10
Fe_2O_3	5.32
FeO	.61
CaO	.12
MgO	1.60
K_2O	7.58
Na_2O	.48
TiO_2	.72
L.O.I.	5.06
S	.012
CO_2	.40
comb. H_2O	4.66

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	8
Mica	32	8
Kaolinite	0	3
C-V-Mo	8	5
Feldspar	14	10

Remarks: little or no chlorite (C) present, feldspar percentage may include some calcite

Other Tests:

pH: 6.15
Workability: slightly plastic, short, fairly smooth
Water of plasticity %: 27.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Buff brown	Soft, crumbly	4.0	24.8	2.49
1900	Buff brown	Soft, crumbly	4.5	23.7	2.50
2000	Lt. brown	Hard	6.0	20.7	2.51
2100	Brown	Very hard	7.5	15.3	2.50
2200	Dk. brown	Steel hard	13.5	4.7	2.45
2300	Dk. brown, glazed	Steel hard	Exp.	1.4	1.95

Bloating Test: Negative

Potential Uses: Brick.

LANCASTER COUNTY

Sample Number

168-8-5

Quadrangle: Lancaster 15'; Lancaster 7½'

Location: Lancaster Brick Company quarry about 0.5 mile east of Rohrerstown.

Geologic Unit: Ledger Formation, Cambrian Age

Description: Light-brown, yellow-orange and yellow-green residual clays, derived from the weathering of the underlying carbonate rocks in the Ledger Formation, are exposed in the quarry. Dark-gray clay occurs in the floor of the quarry in places and may represent the proximity to bedrock. The overburden is about one foot thick.

Attitude of Bedding: Beds not exposed

Sampled Interval: Channel sample taken from one to six feet vertically below surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	55.20
Al_2O_3	16.40
Fe_2O_3	11.39
FeO	.12
CaO	.18
MgO	.73
K_2O	6.60
Na_2O	.60
TiO_2	.77
L.O.I.	7.97
S	.014
CO_2	.92
comb. H_2O	5.26
H_2O @ 120°C	1.79

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz		
Mica		
Kaolinite	No data; X-ray intensities too low for interpretation	
C-V-Mo		
Feldspar		

Other Tests:

pH: 6.6
Workability: fairly plastic and smooth
Water of plasticity %: 28.0
% Drying shrinkage: 5.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Brown	Soft, crumbly	6.5	19.9	2.72
1900	Brown	Soft, crumbly	9.0	16.8	2.70
2000	Dk. brown	Fairly hard	12.5	9.7	2.66
2100	Dk. brown	Very hard	18.0	2.8	2.51
2200	Dk. brown	Steel hard	Exp.		
2300	Melted—expanded				

Bloating Test: Negative

Potential Uses: Brick, tile; possibly sintered aggregate.

LANCASTER COUNTY

Sample Number

178-1-1

Quadrangle: New Holland 15'; Ephrata 7½'

Location: Glen Gery Shale Brick Corporation quarry located about one half mile southwest of the center of the city of Ephrata and about 1000 feet southwest of the Glen Gery office in Ephrata.

Geologic Unit: Cocalico Formation, Ordovician Age

Description: Yellow-brown and yellow-orange clay, formed from the weathering of Cocalico shale, is exposed in the quarry walls. Greenish-gray shale fragments occur throughout the clay, but their concentration increases with depth as bedrock is approached. Complex folding is evident in the shale. The quarry is about 20 feet deep and is floored on carbonate rocks. The upper 1 to 2 feet in the quarry consists of soil overburden.

Attitude of Bedding: None taken because of complex folding

Sampled Interval: Channel sample taken from 1½ to 11½ feet vertically below the surface

Type of Material: clay and shale

Chemical Analysis:

	%
SiO_2	62.30
Al_2O_3	16.50
Fe_2O_3	6.76
FeO	1.76
CaO	.08
MgO	1.75
K_2O	3.90
Na_2O	.35
TiO_2	.82
L.O.I.	5.76
S	.01
CO_2	.48
comb. H_2O	5.10
H_2O @ 120°C	.18

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	41	8
Mica	38	8
Kaolinite	3	3
C-V-Mo	17	8
Feldspar	1	3

Other Tests:

pH: 5.05
Workability: fair plasticity, short and gritty
Water of plasticity %: 26.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Buff brown	Soft, crumbly	4.0	17.9	2.49
1900	Buff brown	Soft, crumbly	4.0	18.0	2.55
2000	Lt. brown	Fairly hard	4.0	14.0	2.54
2100	Brown	Very hard	6.0	10.3	2.52
2200	Dk. brown	Steel hard	7.5	6.4	2.50
2300	Dk. brown	Steel hard	11.0	2.4	2.44

Bloating Test: Slight

Potential Uses: Brick.

LANCASTER COUNTY

Sample Number

178-4-2

Quadrangle: New Holland 15'; Leola 7½'

Location: Exposure about one mile west-southwest of Brownstown on the southeast side of the Lancaster Turnpike, about 1300 feet northeast of the place where the Turnpike crosses Cocalico Creek.

Geologic Unit: Cocalico Formation, Ordovician Age

Description: The exposure is made up of tan and reddish-brown clay containing shale fragments. The height of the exposure is about 10 feet.

Sampled Interval: Channel sample taken from 2 to 8 feet vertically below the surface

Type of Material: clay and shale

Chemical Analysis:

	%
SiO_2	68.60
Al_2O_3	13.90
Fe_2O_3	6.10
FeO	.77
CaO	.08
MgO	1.28
K_2O	2.85
Na_2O	.24
TiO_2	.68
L.O.I.	5.44
S	.020
CO_2	.57
comb. H_2O	4.87

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	46	2
Mica	36	8
Kaolinite	9	6
C-V-Mo	5	3
Feldspar	0	2

Remarks: carbonates present; little or no vermiculite (V) present

Other Tests:

pH: 4.5
Workability: not plastic, short
Water of plasticity %: 30.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff brown	Soft, crumbly	1.0	25.7	2.64
1900	Buff brown	Soft, crumbly	1.5	23.5	2.66
2000	Buff brown	Soft, crumbly	3.0	21.3	2.62
2100	Lt. brown	Hard	5.0	16.7	2.59
2200	Dk. brown	Steel hard	8.5	11.5	2.54
2300	Dk. brown	Steel hard	8.5	7.0	2.45

Bloating Test: Negative

Potential Uses: Could be blended with other clays for brick.

LANCASTER COUNTY

Sample Number

178-8-4

Quadrangle: New Holland 15'; New Holland 7½'

Location: Exposure at the northeast corner of the road intersection about 0.25 mile southwest of Hickory Grove School and about 1.2 miles east of Gordonville.

Geologic Unit: Ledger Formation, Cambrian Age

Description: Moderate-reddish-orange to moderate-reddish-brown sandy clay overlies the Ledger dolomite. The exposure is about five feet in height.

Sampled Interval: Vertical 5-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	71.35
Al_2O_3	13.00
Fe_2O_3	4.88
FeO	.38
CaO	.08
MgO	.83
K_2O	4.37
Na_2O	.22
TiO_2	.45
L.O.I.	4.39
S	.016
CO_2	.33
comb. H_2O	4.06

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	46	8
Mica	24	8
Kaolinite	6	4
C-V-Mo	3	3
Feldspar	13	6

Remarks: some vermiculite (V) or montmorillonite (Mo) present

Other Tests:

pH: 6.3
Workability: not plastic, short and sandy
Water of plasticity %: 22.0
% Drying shrinkage: 4.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. orange brown	Soft, crumbly	5.0	21.1	2.73
1900	Dk. orange brown	Soft, crumbly	5.0	20.4	2.73
2000	Dk. red brown	Soft, crumbly	5.0	19.2	2.71
2100	Dk. brown red	Soft, crumbly	5.0	18.8	2.71
2200	Dk. brown red	Fairly hard	5.0	17.0	2.66
2300	Very dk. brown	Hard	5.0	13.5	2.59

Bloating Test: Negative

Potential Uses: Excellent pigmenting material.

LANCASTER COUNTY

Sample Number

179-7-2

Quadrangle: Quarryville 15'; Wakefield 7½'

Location: Exposure along the east side of the Pennsylvania Railroad tracks about 1.4 miles north-northwest of the town of Peach Bottom.

Geologic Unit: Peach Bottom Slate, probably Lower Paleozoic Age

Description: Blue-black slate and slaty schist are exposed in a railroad cut about 100 feet high. Secondary quartz material fills numerous joints. A minor amount of pyrite occurs within the rock.

Attitude of Cleavage: N40-50E; dips from 80N to 70S

Sampled Interval: Grab sample collected from a 250-foot section in the exposure

Type of Material: slate

Chemical Analysis:

	%
SiO_2	56.80
Al_2O_3	22.90
Fe_2O_3	3.93
FeO	4.56
CaO	.09
MgO	.87
K_2O	3.62
Na_2O	.51
TiO_2	1.23
L.O.I.	5.44
S	.15
CO_2*	3.37
comb. H_2O	1.92

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	39	8
Mica	40	8
Kaolinite	0	4
C-V-Mo	6	4
Feldspar	1	3

Remarks: C-V-Mo percentage is all chlorite; carbonates present

Other Tests:

pH: 7.4
Workability: not plastic, short and mealy
Water of plasticity %: 21.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	0.5	29.0	2.74
1900	Dk. buff brown	Soft, crumbly	0.5	26.6	2.76
2000	Dk. buff brown	Soft, crumbly	6.0	25.2	2.75
2100	Brown	Soft, crumbly	7.0	20.7	2.73
2200	Dk. brown	Very hard	5.0	16.6	2.54
2300	Dk. brown	Steel hard	5.0	13.4	2.15

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.02	125.8	7.8	No bloating
2000	1.91	119.0	6.2	No bloating
2100	1.52	94.7	11.3	No bloating
2200	1.07	66.7	13.7	Fair bloating

Evaluation: Possibly sintered aggregate.

Potential Uses: Possibly sintered aggregate.

LANCASTER COUNTY

Sample Number

188-4-1

Quadrangle: Honeybrook 15′; Honeybrook 7½′

Location: Quarry operated by Narvon Mines, Ltd. about 0.25 mile west of the town of Narvon.

Geologic Unit: Chickies Formation, Cambrian Age

Description: The material being quarried consists of a light-gray residual clay which has apparently developed from the weathering of a schistose section in the upper part of the Chickies quartzite. The clay is reported to be up to 60 feet thick. Some sandy layers and quartz veins occur within the deposit.

Attitude of Bedding: N80W; 32S

Sampled Interval: A 15-foot channel sample was taken in the west wall of the pit

Type of Material: clay

Chemical Analysis:

	%
SiO_2	75.00
Al_2O_3	15.70
Fe_2O_3	.61
FeO	,64
CaO	.05
MgO	.40
K_2O	1.75
Na_2O	.07
TiO_2	.93
L.O.I.	4.78
S	.004
CO_2	.15
comb. H_2O	4.60
H_2O @ 120°C	.03

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	50	10
Mica	21	6
Kaolinite	24	10
C-V-Mo	0	3
Feldspar	0	3

Other Tests:

pH: 4.5
Workability: not plastic, short and gritty
Water of plasticity %: 20.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800		Too crumbly for properties			
1900		Too crumbly for properties			
2000		Too crumbly for properties			
2100		Too crumbly for properties			
2200		Too crumbly for properties			
2300	Gray	Soft, crumbly	4.5	26.4	2.65
2400	Gray	Soft, crumbly	5.0	23.4	2.46

Bloating Test: Negative

Potential Uses: Filler; with beneficiation foundry and steelwork refractories; and brick. Also reported to be used as a carrier in insecticides and as a flocculant in water treatment.

LAWRENCE COUNTY

Sample Number

5-1-3

Quadrangle: New Castle 15' New Castle South 7½'

Location: Medusa Cement Company quarry about 3.25 miles north-northwest of the Medusa plant in Wampum, Pennsylvania.

Geologic Unit: Middle Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Light- to medium-gray, plastic underclay to the middle Kittanning coal is exposed about 60 feet below the surface in the stripping operation. The thickness of the clay is 2½ feet.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 2½-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	52.50
Al_2O_3	25.80
Fe_2O_3	3.86
FeO	.76
CaO	.69
MgO	.82
K_2O	2.04
Na_2O	.24
TiO_2	1.45
L.O.I.	11.82
S	1.26
CO_2*	1.76
comb. H_2O	10.06
H_2O @ 120°C	2.49

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	10
Mica	33	8
Kaolinite	10	9
C-V-Mo	3	3
Feldspar	1	3

Remarks: gypsum and carbonates present

Other Tests:

pH: 3.4
Workability: fairly plastic and smooth
Water of plasticity %: 22.2
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Buff orange	Soft, crumbly	7.5	15.3	2.57
1900	Buff orange	Hard	10.0	13.1	2.59
2000	Buff orange	Steel hard	14.0	7.6	2.55
2100	Lt. red brown	Steel hard	17.5	1.6	2.39
2200	Gray red	Steel hard	Exp.	4.0	1.94
2300	Gray red	Steel hard	Exp.	11.2	2.06

Bloating Test: Negative

Potential Uses: Brick and possibly sintered aggregate.

LAWRENCE COUNTY

Sample Number

5-1-5

Quadrangle: New Castle 15′ New Castle South 7½′

Location: Coal stripping operation about 0.5 mile southeast of West Pittsburgh, Pa.

Geologic Unit: Lower Kittanning shale, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Yellow-gray to olive-gray, thin-bedded, shales occur from 6 to 18 feet above the top of the Lower Kittanning coal. Upon weathering, the shale breaks down into soft, tan and gray, hackly fragments.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample taken from 6 to 18 feet above the top of the Lower Kittanning coal

Type of Material: shale

Chemical Analysis:

	%
SiO_2	59.80
Al_2O_3	19.15
Fe_2O_3	6.04
FeO	1.37
CaO	.29
MgO	1.08
K_2O	3.11
Na_2O	.37
TiO_2	1.13
L.O.I.	7.65
S	.084
CO_2*	3.17
comb. H_2O	4.48
H_2O @ 120°C	1.26

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	8
Mica	43	8
Kaolinite	6	5
C-V-Mo	2	2
Feldspar	0	2

Remarks: some carbonates present

Other Tests:

pH: 7.1
Workability: fairly plastic and smooth
Water of plasticity %: 19.6
% Drying shrinkage: 1.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	17.8	2.70
1900	Dk. buff brown	Fairly hard	5.0	15.4	2.69
2000	Brown	Steel hard	9.5	11.6	2.68
2100	Dk. brown	Steel hard	10.5	6.1	2.60
2200	Very dk. brown	Steel hard	Slight expansion	3.2	2.40
2300	Gray black	Steel hard	Slight expansion	2.9	2.23

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.92	119.6	9.0	No bloating
2000	1.90	118.4	8.3	No bloating
2100	1.04	64.8	8.9	Fair bloating
2200	0.98	61.0	8.2	Good bloating, slightly sticky
2300	0.94	58.6	7.6	Overbloated and very sticky

Evaluation: Good. Bloating range rather short, but with close temperature control this shale would make a good lightweight aggregate by the rotary kiln process.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	37.4
—1/4 + 1/8	36.3
—1/8 + 16	26.3
Total	100.0

Screen analysis

Size	Percent retained
+3/8	20.4
—3/8 + 1/4	19.8
—1/4 + 8	19.2
— 8 + 16	13.8
—16 + 35	12.0
—35 + 65	7.7
—65	7.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1865	1915
Optimum	1940	1970
Maximum	1960	2040

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	108
Fired	60
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular & Rounded
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to brown

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.^{3}	% Abs.
—3/4 + 1/2	1.45	90.3	9.9
—1/2 + 1/4	1.43	89.1	8.5
—1/4 + 8 mesh	1.63	101.5	9.5

Screen analysis

Size	Percent retained
+3/8	31.7
—3/8 + 1/4	49.9
—1/4 + 8	16.5
— 8 + 16	1.2
—16 + 35	.3
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.51
Lb/Ft^3	94
Compression (PSI)	2837
Color (colorimeter)	29
Cure	Autoclave
% Abs.	4.2

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.44
Lb/Ft^3	90
Compression (PSI)	1884
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	3.8

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.63	Bulk Sp. Gr.	1.68
Lb/Ft^3	102	Lb/Ft^3	105
Compression (PSI)	5202	Compression (PSI)	4064
Color (colorimeter)	36	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	7.3	% Abs.	11.7

Potential Uses: Brick, floor tile, and good lightweight aggregate.

LAWRENCE COUNTY

Sample Number

5-3-4A

Quadrangle: New Castle 15'; New Castle South 7½'

Location: Abandoned coal stripping operation about 1.75 miles northeast of Union Valley, Pennsylvania.

Geologic Unit: Middle Kittanning horizon, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Light-olive-gray, thin-bedded shales occur from 10 to 18 feet stratigraphically above the top of the Middle Kittanning coal. The beds average about ¼ inch in thickness. Weathered fragments of the shale are predominantly platy in shape and tan in color.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample taken from 10 to 18 feet above the top of the Middle Kittanning coal.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	58.80
Al_2O_3	19.72
Fe_2O_3	6.30
FeO	1.98
CaO	.19
MgO	1.34
K_2O	3.19
Na_2O	.52
TiO_2	.95
L.O.I.	6.99
S	.082
CO_2*	2.10
comb. H_2O	4.89
H_2O @ 120°C	.87

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	34	8
Mica	44	8
Kaolinite	9	7
C-V-Mo	4	3
Feldspar	0	3

Remarks: some carbonates present

Other Tests:

pH: 5.5
Workability: not very plastic, slightly short
Water of plasticity %: 24.0
% Drying shrinkage: 4.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	1.0	19.5	2.63
1900	Dk. buff brown	Soft, crumbly	2.5	18.4	2.65
2000	Lt. brown	Soft, crumbly	4.5	15.7	2.66
2100	Brown	Steel hard	6.5	10.8	2.63
2200	Very dk. brown	Steel hard	10.0	2.5	2.42
2300	Gray black	Steel hard	11.0	11.0	2.34

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.28	142.0	7.6	No bloating
2000	2.08	129.6	7.5	No bloating
2100	1.40	87.2	7.2	Slight bloating
2200	0.76	47.3	6.5	Excellent bloating
2300	0.86	53.6	9.9	Overbloated and sticky

Evaluation: Good lightweight aggregate material. Uniform expansion and low absorption.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	41.6
—1/4 + 1/8	34.2
—1/8 + 16	24.2
Total	100.0

Screen analysis

Size	Percent retained
+3/8	19.9
—3/8 + 1/4	22.7
—1/4 + 8	18.6
— 8 + 16	13.2
—16 + 35	11.6
—35 + 65	4.9
—65	9.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1980	2030
Optimum	1988	2000
Maximum	2010	2100

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	107
Fired	54
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	11:00
Particle shape	Angular & Rounded
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.³	% Abs.
—3/4 + 1/2	NA	NA	NA
—1/2 + 1/4	1.38	86.0	8.4
—1/4 + 8 mesh	1.47	91.6	8.0

Screen analysis

Size	Percent retained
+3/8	30.4
—3/8 + 1/4	47.2
—1/4 + 8	19.4
— 8 + 16	2.4
—16 + 35	.2
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.41
Lb/Ft³	88
Compression (PSI)	4674
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.7

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.44
Lb/Ft³	90
Compression (PSI)	2927
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	5.5

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.50	Bulk Sp. Gr.	1.52
Lb/Ft^3	93	Lb/Ft^3	95
Compression (PSI)	5845	Compression (PSI)	3942
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	5.5	% Abs.	6.0

Potential Uses: Good lightweight aggregate; possibly brick.

LAWRENCE COUNTY

Sample Number

5-3-4B

Quadrangle: New Castle 15'; New Castle South 7½'

Location: Abandoned coal stripping operation about 1.75 miles northeast of Union Valley, Pennsylvania.

Geologic Unit: Middle Kittanning horizon, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: Olive-gray and light-olive-gray, thin-bedded shales and siltstones occur 18 to 25 feet stratigraphically above the top of the Middle Kittanning coal. The average thickness of the beds is less than ½ inch.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample from 18 to 25 feet above the top of the Middle Kittanning coal.

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	59.60
Al_2O_3	19.85
Fe_2O_3	5.01
FeO	2.13
CaO	.23
MgO	1.40
K_2O	3.28
Na_2O	.63
TiO_2	1.00
L.O.I.	6.84
S	.052
CO_2*	1.86
comb. H_2O	4.98
H_2O @ 120°C	.72

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	39	6
Mica	36	6
Kaolinite	9	6
C-V-Mo	7	4
Feldspar	1	3

Remarks: carbonates present

Other Tests:

pH: 6.35
Workability: fair plasticity, slightly short
Water of plasticity %: 24.8
% Drying shrinkage: 6.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	24.5	2.70
1900	Dk. buff brown	Soft, crumbly	5.0	21.5	2.68
2000	Lt. brown	Hard	6.0	16.0	2.66
2100	Brown	Steel hard	10.0	9.2	2.61
2200	Very dk. brown	Steel hard	14.5	2.5	2.36
2300	Very dk. brown	Steel hard	Exp.	3.3	2.17

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.91	119.0	12.3	No bloating
2000	1.65	102.8	9.7	No bloating
2100	1.28	79.7	9.6	Fair bloating
2200	1.03	64.2	9.5	Good bloating
2300	0.71	44.2	9.5	Overbloated and very sticky

Evaluation: Good lightweight aggregate material. Uniform expansion and low absorption.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	46.7
—1/4 + 1/8	30.3
—1/8 + 16	23.0
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	14.2
—3/8 + 1/4	27.3
—1/4 + 8	17.6
— 8 + 16	13.4
—16 + 35	11.1
—35 + 65	7.2
—65	9.2
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1990	2040
Optimum	2000	2038
Maximum	2055	2135

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	105
Fired	49
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular & Rounded
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to dk. black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.1	67.9	8.2
—1/2 + 1/4	1.3	79.7	9.6
—1/4 + 8 mesh	1.4	84.1	5.8

Screen analysis

Size	*Percent retained*
+3/8	52.9
—3/8 + 1/4	35.9
—1/4 + 8	9.7
— 8 + 16	.8
—16 + 35	.2
—35 + 65	.2
—65	.3
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.25
Lb/Ft^3	78
Compression (PSI)	4170
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	3.8

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.32
Lb/Ft^3	82
Compression (PSI)	3016
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	3.9

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.32	Bulk Sp. Gr.	1.45
Lb/Ft^3	82	Lb/Ft^3	90
Compression (PSI)	3495	Compression (PSI)	3780
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	3.7	% Abs.	6.0

Potential Uses: Brick, floor tile, and good lightweight aggregate.

LAWRENCE COUNTY

Sample Number

5-5-1

Quadrangle: New Castle 15'; New Castle South 7½'

Location: North side of the Medusa Cement Company quarry located about 2.5 miles north-northeast of Wampum, Pennsylvania.

Geologic Unit: Lower Kittanning underclay, Kittanning Formation, Allegheny Group, Pennsylvanian Age

Description: A very-light-to light-gray, plastic underclay, 5 feet thick, underlies the Lower Kittanning coal. The underclay is close to the surface in the quarry, being overlain by about 5 feet of glacial till. It is currently being stripped off as waste to quarry the Vanport limestone which occurs about 30 feet below the underclay.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 5-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	65.40
Al_2O_3	22.70
Fe_2O_3	1.21
FeO	.38
CaO	.10
MgO	.47
K_2O	2.42
Na_2O	.26
TiO_2	1.14
L.O.I.	5.88
S	.015
CO_2*	2.61
comb. H_2O	3.27
H_2O @ 120°C	.91

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	39	8
Mica	31	7
Kaolinite	23	8
C-V-Mo	1	2
Feldspar	0	3

Remarks: carbonates present

Other Tests:

pH: 6.55
Workability: fairly plastic and smooth, slightly short
Water of plasticity %: 18.6
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	5.0	15.0	2.56
1900	Lt. buff	Soft, crumbly	5.0	14.3	2.58
2000	Lt. buff	Soft, crumbly	5.5	12.1	2.57
2100	Buff	Hard	7.5	9.1	2.55
2200	Buff gray	Steel hard	9.0	6.3	2.49
2300	Buff gray	Steel hard	9.0	7.0	2.47

Bloating Test: Negative

Pyrometric cone equivalent: 23 **Cone color:** Dark tan

Potential Uses: Low-duty refractory products; possibly chimney flue tile and decorative brick.

LAWRENCE COUNTY

Sample Number

5-5-2

Quadrangle: New Castle 15'; New Castle South 7½'

Location: South side of the Medusa Cement Company quarry located about 2.5 miles north-northeast of Wampum, Pennsylvania.

Geologic Unit: Upper Clarion horizon, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-to medium-dark-gray, thin-bedded silty shales occur from 6½ to 13½ feet below the base of the Vanport limestone. The stratigraphic interval from the Vanport limestone down to the sampled horizon consists of 2 feet of underclay; 3 feet of carbonaceous, fissile shale; and 1½ feet of sandstone. The sampled interval is underlain by sandstone.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 7-foot channel sample taken from 6½ to 13½ feet below the Vanport limestone.

Type of Material: silty shales

Chemical Analysis:

	%
SiO_2	61.60
Al_2O_3	19.15
Fe_2O_3	3.31
FeO	2.74
CaO	.48
MgO	1.07
K_2O	3.31
Na_2O	.33
TiO_2	1.05
L.O.I.	6.94
S	.19
CO_2*	2.55
comb. H_2O	4.39
H_2O @ 120°C	.73

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	41	8
Mica	37	8
Kaolinite	12	8
C-V-Mo	4	3
Feldspar	0	2

Remarks: carbonates and zeolite? present; some vermiculite (V) or montmorillonite (Mo)

Other Tests:

pH: 4.5
Workability: not very plastic, short, slightly fatty
Water of plasticity %: 21.8
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	0.5	22.1	2.73
1900	Dk. buff brown	Soft, crumbly	4.0	20.2	2.74
2000	Brown red	Fairly hard	5.0	15.1	2.71
2100	Dk. red brown	Steel hard	10.0	8.5	2.63
2200	Very dk. brown	Steel hard	12.5	3.8	2.55
2300	Very dk. brown	Steel hard	Exp.	0.0	2.24

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.01	125.2	7.6	No bloating
2000	1.70	105.9	8.5	No bloating
2100	1.32	82.2	9.8	Slight expansion
2200	1.06	66.0	11.7	Good bloating
2300	0.98	61.8	9.8	Overbloated and sticky

Evaluation: Although the bloating temperature is rather high, this shale would probably make a good lightweight aggregate by either the rotary kiln or sintering process.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Unweathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	47.9
—1/4 + 1/8	31.6
—1/8 + 16	20.5
Total	100.0

Screen analysis

Size	Percent retained
+3/8	20.4
—3/8 + 1/4	28.0
—1/4 + 8	18.4
— 8 + 16	12.0
—16 + 35	9.0
—35 + 65	6.4
—65	5.8
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1980	1930
Optimum	1980	2020
Maximum	2010	2090

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	108
Fired	60
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	11:00
Particle shape	Angular & Rounded
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	U
Color	Br. to gray

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.^{3}	% Abs.
—3/4 + 1/2	1.37	85.4	10.2
—1/2 + 1/4	1.47	91.6	11.5
—1/4 + 8 mesh	1.61	100.3	9.7

Screen analysis

Size	Percent retained
+3/8	35.9
—3/8 + 1/4	39.1
—1/4 + 8	18.6
— 8 + 16	5.2
—16 + 35	.8
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.50
Lb/Ft^3	93
Compression (PSI)	5121
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.2

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.50
Lb/Ft^3	93
Compression (PSI)	4081
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	4.8

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.57	Bulk Sp. Gr.	1.54
Lb/Ft^3	98	Lb/Ft^3	96
Compression (PSI)	6601	Compression (PSI)	5389
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% abs.	5.9	% Abs.	5.6

Potential Uses: Brick and good lightweight aggregate; possibly floor tile.

LEBANON COUNTY

Sample Number

157-3-4

Quadrangle: Hummelstown 15'; Indiantown Gap 7½'

Location: An old quarry on the south side of State Route 72 at Swatara Gap about 12 miles north of Lebanon.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: About 235 stratigraphic feet of medium-gray, fossiliferous shales and some interbedded siltstones exposed in the quarry. The beds dip very steeply to the northwest. The exposed section of Martinsburg is in the upper part of the formation as evidenced by its conformable contact with the younger Tuscarora quartzite of Silurian Age in the quarry.

Attitude of Bedding: N50E; 75NW

Sampled Interval: Channel sample through twenty stratigraphic feet of section at the northern end of the quarry.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.30
Al_2O_3	14.45
Fe_2O_3	5.45
FeO	2.30
CaO	.21
MgO	1.71
K_2O	4.16
Na_2O	.66
TiO_2	1.02
L.O.I.	5.69
S	.010
CO_2	.66
comb. H_2O	5.03

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	37	8
Mica	48	10
Kaolinite	1	4
C-V-Mo	4	3
Feldspar	1	3

Other Tests:

pH: 6.0
Workability: not plastic, short, mealy
Water of plasticity %: 16.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	3.5	14.3	2.67
1900	Lt. brown	Soft, crumbly	5.0	13.2	2.66
2000	Brown	Hard	5.0	10.8	2.66
2100	Med. brown	Steel hard	10.0	5.3	2.56
2200	Dk. brown	Steel hard	Exp.	0.9	2.08
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: Approx. ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.69	105.3	4.4	No bloating
2000	1.35	84.1	5.1	Slight bloating
2100	1.02	63.5	4.6	Excellent bloating
2200	0.75	46.7	4.4	Overbloated and very sticky

Evaluation: Excellent lightweight aggregate possibilities. Adequate firing range; aggregate has good strength and low absorption.

Potential Uses: Brick, excellent lightweight aggregate possibilities.

LEBANON COUNTY

Sample Number

157-6-1A

Quadrangle: Hummelstown 15'; Palmyra 7½'

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Pale-red-purple shales with some beds of greenish-gray shales, measuring sixty stratigraphic feet, are exposed along the roadway from 70 to 130 feet north of telephone pole ME IC 5781. The height of the exposure in this section is from 2 to 20 feet.

Attitude of Bedding: N80W; 84N

Sampled Interval: Composite sample representing 60 stratigraphic feet of section.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	60.00
Al_2O_3	19.70
Fe_2O_3	5.97
FeO	2.46
CaO	.07
MgO	.98
K_2O	5.00
Na_2O	.52
TiO_2	.82
L.O.I.	4.41
S	.004
CO_2	.26
comb. H_2O	4.15

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	32	8
Mica	47	8
Kaolinite	8	6
C-V-Mo	4	3
Feldspar	0	3

Other Tests:

pH: 7.9
Workability: not plastic, short and mealy
Water of plasticity %: 17.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Sandy brown	Soft, crumbly	1.0	14.3	2.75
1900	Sandy brown	Soft, crumbly	1.0	12.6	2.73
2000	Brown	Fairly hard	2.5	9.9	2.70
2100	Dk. brown	Hard	2.5	8.0	2.69
2200	Gray black	Steel hard	2.5	5.8	2.59
2300	Melted and expanded				

Bloating Test: Slight

Potential Uses: Possibly brick and sintered aggregate.

LEBANON COUNTY

Sample Number

157-6-1B

Quadrangle: Hummelstown 15'; Palmyra 7½'

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Sixty stratigraphic feet of gray-red and purple shales are exposed south of telephone pole marked ME K 5783. This section represents the northern portion of an exposure which extends for a distance of over 550 feet along the roadway.

Attitude of Bedding: N80W; 84N

Sampled Interval: Composite sample from sixty stratigraphic feet of section.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.50
Al_2O_3	17.05
Fe_2O_3	5.38
FeO	1.77
CaO	.11
MgO	1.34
K_2O	6.00
Na_2O	.26
TiO_2	.95
L.O.I.	4.58
S	.008
CO_2	.33
comb. H_2O	4.25

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	32	8
Mica	51	8
Kaolinite	0	3
C-V-Mo	3	2
Feldspar	1	2

Other Tests:

pH: 7.8
Workability: not plastic, short and mealy
Water of plasticity %: 19.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff brown	Soft, crumbly	1.0	17.2	2.67
1900	Dk. buff brown	Soft, crumbly	2.5	13.8	2.61
2000	Dk. brown	Fairly hard	5.0	8.3	2.59
2100	Dk. brown	Hard	7.5	4.9	2.54
2200	Dk. brown	Steel hard	Exp.		
2300	Melted and expanded				

Bloating Test: Slight

Potential Uses: Possibly brick and sintered aggregate.

LEBANON COUNTY

Sample Number

157-6-1C

Quadrangle: Hummelstown 15'; Palmyra 7½'

Location: Exposure along the east side of State Route 934 about 0.8 mile northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Forty stratigraphic feet of moderate-yellow-brown and gray-orange, thin-bedded shales are exposed to the south of a point about 60 feet south of telephone pole marked ME K 5783. The height of the exposure is about 10 feet.

Attitude of Cleavage: N65E; 45S

Sampled Interval: Composite sample taken from forty stratigraphic feet.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.40
Al_2O_3	17.30
Fe_2O_3	6.42
FeO	1.44
CaO	.12
MgO	1.19
K_2O	5.10
Na_2O	.55
TiO_2	.88
L.O.I.	5.53
S	.01
CO_2	.40
comb. H_2O	4.76
H_2O @ 120°C	.37

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	8
Mica	52	10
Kaolinite	1	3
C-V-Mo	3	3
Feldspar	1	3

Other Tests:

pH: 7.7
Workability: not very plastic, short and mealy
Water of plasticity %: 22.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	19.7	2.71
1900	Dk. buff brown	Soft, crumbly	6.0	16.2	2.69
2000	Dk. brown	Fairly hard	10.0	8.3	2.61
2100	Dk. brown	Hard	11.0	5.2	2.58
2200	Very dk. brown	Steel hard	11.0	2.8	2.48
2300	Gray black	Steel hard	Exp.		

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.26	140.8	5.0	No bloating
2000	2.44	152.0	2.3	No bloating
2100	2.09	130.2	2.6	Slight bloating
2200	1.30	81.0	3.0	Fair bloating

Evaluation: Poor results may be due to the amount of weathered shale in the sample.

Potential Uses: Possibly brick.

LEBANON COUNTY

Sample Number

157-6-2

Quadrangle: Hummelstown 15'; Palmyra 7½'

Location: Exposure along the east side of State Route 934 near the southern boundary of Bellegrove, about 2.7 miles northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Moderately weathered shales of the Martinsburg Formation are exposed in a roadcut for a distance of about 200 feet. The colors of the shale range from light olive gray to yellow gray.

Attitude of Bedding: Strike approximately EW, dips steeply south

Sampled Interval: Composite sample from entire exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	57.50
Al_2O_3	19.60
Fe_2O_3	7.23
FeO	1.77
CaO	.19
MgO	1.20
K_2O	4.08
Na_2O	.43
TiO_2	1.02
L.O.I.	6.94
S	.014
CO_2	.55
comb. H_2O	6.39

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	45	8
Kaolinite	1	3
C-V-Mo	12	5
Feldspar	0	3

Other Tests:

pH: 7.4
Workability: not plastic, short and mealy
Water of plasticity %: 24.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff brown	Soft, crumbly	4.0	21.8	2.76
1900	Dk. buff brown	Soft, crumbly	4.0	19.1	2.73
2000	Med. brown	Fairly hard	7.5	12.0	2.62
2100	Dk. brown	Hard	8.0	10.4	2.62
2200	Dk. brown	Very hard	8.0	7.4	2.55
2300	Gray black	Steel hard	Exp.		

Bloating Test: Negative

Potential Uses: Possibly brick.

LEBANON COUNTY

Sample Number

157-6-3

Quadrangle: Hummelstown 15'; Indiantown Gap 7½'

Location: Exposure along the east side of State Highway 934 about 4.3 miles northwest of Annville.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Grayish-red to moderate-red shale, much of which has weathered grayish-orange, is exposed for a distance of several hundred feet along the roadcut. The height of the exposure is from six to seven feet

Attitude of Bedding: N45E; 40SE

Sampled Interval: Composite sample from southern half of the exposure.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	57.00
Al_2O_3	20.94
Fe_2O_3	8.01
FeO	1.04
CaO	.12
MgO	.93
K_2O	4.10
Na_2O	.83
TiO_2	.92
L.O.I.	6.08
S	.01
CO_2	.26
comb. H_2O	4.97
H_2O @ 120°C	.85

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	40	10
Mica	44	10
Kaolinite	1	3
C-V-Mo	3	2
Feldspar	1	3

Other Tests:

pH: 7.2
Workability: not very plastic, short
Water of plasticity %: 20.0
% Drying shrinkage: 1.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff brown	Soft, crumbly	3.5	18.0	2.75
1900	Dk. buff brown	Soft, crumbly	5.0	14.6	2.73
2000	Brown	Fairly hard	7.5	10.2	2.69
2100	Dk. brown	Hard	10.0	6.5	2.64
2200	Dk. brown	Very hard	10.0	4.8	2.58
2300	Gray black	Steel hard	10.0	4.1	2.53
**2000		Steel hard	4.7	3.4	2.66
**2050		Steel hard	6.3	1.2	2.61

** Additional firing data on miniature pressed brick with a two hour soak.

Bloating Test: Negative

Potential Uses: Brick.

LEBANON COUNTY

Sample Number

167-1-1

Quadrangle: Lebanon 15′; Fredericksburg 7½′

Location: Outcrop along the north side of State Route 343 about 0.3 mile west of Fredericksburg.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Grayish-red, thin-bedded shale, interbedded with minor amounts of yellow-green shale and silty shale, is exposed along the road for a distance of several hundred feet. The height of the exposure is about 13 feet.

Attitude of Bedding: N45E; 35N

Sampled Interval: Channel sample from 3 to 13 feet vertically below the surface.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	59.70
Al_2O_3	17.05
Fe_2O_3	7.96
FeO	.60
CaO	.23
MgO	1.46
K_2O	5.10
Na_2O	.80
TiO_2	.92
L.O.I.	6.13
S	.01
CO_2	.51
comb. H_2O	4.96
H_2O @ 120°C	.66

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	52	10
Kaolinite	0	2
C-V-Mo	3	2
Feldspar	2	3

Other Tests:

pH: 5.7
Workability: fair plasticity, short
Water of plasticity %: 23.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Fairly hard	7.5	11.5	2.56
1900	Lt. brown	Hard	7.5	9.4	2.53
2000	Brown	Steel hard	9.0	5.6	2.52
2100	Med. brown	Steel hard	9.0	2.3	2.45
2200	Dk. brown	Steel hard	Exp.	1.3	1.98
2300	Dk. brown	Expanded, vitreous, melting			1.49

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.17	135.2	3.3	No bloating
1900	1.84	114.6	4.3	Very slight bloating
2000	1.66	103.4	3.9	Slight bloating
2100	1.02	63.5	4.5	Good bloating
2200	1.01	62.9	3.4	Good bloating, sticky

Evaluation: Good lightweight aggregate.

Potential Uses: Brick and tile, good lightweight aggregate.

LEBANON COUNTY

Sample Number

167-1-2

Quadrangle: Lebanon 15'; Fredericksburg 7½'

Location: An exposure on the south side of State Route 343 about 2.5 miles northwest of Fredericksburg.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Light-olive-gray, greenish-yellow, and tan, high weathered shales are interbedded with a few silty and sandy beds along a road exposure. The shales break readily into small platy fragments.

Attitude of Bedding: N80E; 33S; attitudes change in exposure because of minor folds.

Sampled Interval: 10-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	58.80
Al_2O_3	17.40
Fe_2O_3	5.63
FeO	1.68
CaO	.79
MgO	1.54
K_2O	4.20
Na_2O	1.57
TiO_2	.95
L.O.I.	7.38
S	.008
CO_2	1.72
comb. H_2O	4.23
H_2O @ 120°C	1.43

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	30	8
Mica	47	10
Kaolinite	6	4
C-V-Mo	5	3
Feldspar	1	2

Remarks: some chlorite (C) and vermiculite (V) or montmorillonite (Mo) present

Other Tests:

pH: 7.2
Workability: fair plasticity, short
Water of plasticity %: 23.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Fairly hard	2.5	12.7	2.56
1900	Lt. brown	Hard	4.0	11.0	2.55
2000	Brown	Steel hard	6.0	6.9	2.50
2100	Med. brown	Steel hard	7.0	3.1	2.39
2200	Dk. brown	Steel hard	Exp.	1.0	2.31
2300	Very dk. brown	Expanded and melting			1.68

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (thin platy) Particle size: $-\frac{1}{2} + \frac{1}{4}''$

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.88	117.1	4.1	Slight bloating
2000	1.15	71.6	4.1	Fair bloating
2100	1.04	64.8	4.5	Good bloating
2200	0.98	61.0	5.2	Overfired and sticky

Evaluation: Good lightweight aggregate.

Potential Uses: Brick and tile, good lightweight aggregate.

LEHIGH COUNTY

Sample Number

196-1-1A

Quadrangle: Allentown 15'

Location: An exposure on the north side of U. S. Route 309 where the road bends sharply to the west near Jordan.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The exposure consists of moderately weathered slate underlain by relatively unweathered slate. This sample is composed of green and tan, weathered slate which extends to a depth of 12 feet below the surface. Iron-staining is common along fractures and cleavage planes in this material. One foot of soil overburden overlies the slate. The exposure extends for a distance of about 600 feet in a direction parallel to the road.

Attitude of Cleavage: N85E; 47S

Sampled Interval: Channel sample of weathered slate taken from 1 to 10 feet below the surface.

Type of Material: slate

Chemical Analysis:

	%
SiO_2	61.40
Al_2O_3	17.20
Fe_2O_3	7.30
FeO	.77
CaO	.07
MgO	1.40
K_2O	4.32
Na_2O	.24
TiO_2	.90
L.O.I.	6.34
S	.010
CO_2	.48
comb. H_2O	5.86

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	37	8
Mica	41	8
Kaolinite	6	4
C-V-Mo	5	3
Feldspar	1	3

Remarks: some chlorite (C) and vermiculite (V) or montmorillonite (Mo) present

Other Tests:

pH: 5.3
Workability: fair plasticity, short with fine grit
Water of plasticity %: 27.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	5.0	22.9	2.71
1900	Dk. buff orange	Hard	7.5	21.0	2.70
2000	Dk. buff orange	Very hard	7.5	15.9	2.65
2100	Brown	Steel hard	10.0	8.2	2.57
2200	Dk. brown	Steel hard	12.5	3.9	2.42
2300	Very dk. brown	Steel hard	12.5	5.1	2.18

Bloating Test: Slight expansion

Potential Uses: Brick.

LEHIGH COUNTY

Sample Number

196-1-1B

Quadrangle: Allentown 15'

Location: An exposure on the north side of U. S. Route 309 where the road bends sharply to the west near Jordan.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: The exposure consists of moderately weathered slate underlain by relatively unweathered slate. This sample represents the unweathered gray slate that underlies 12 feet of weathered material. Some iron-staining is present along the cleavage and fracture surfaces or the sampled slate. The exposure extends for a distance of about 600 feet in a direction parallel to the road.

Attitude of Cleavage: N85E; 47S

Sampled Interval: 20-foot channel sample

Type of Material: slate

Chemical Analysis:

	%
SiO_2	60.80
Al_2O_3	13.50
Fe_2O_3	5.77
FeO	1.38
CaO	.20
MgO	1.84
K_2O	3.97
Na_2O	.82
TiO_2	.79
L.O.I.	10.90
S	.030
CO_2	.73
comb. H_2O	10.17

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	8
Mica	45	10
Kaolinite	0	2
C-V-Mo	8	4
Feldspar	1	2

Other Tests:

pH: 6.3
Workability: not plastic, short and fatty
Water of plasticity %: 19.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	3.0	16.2	2.66
1900	Dk. buff orange	Fairly hard	3.0	14.5	2.61
2000	Brown	Very hard	3.0	11.3	2.58
2100	Dk. brown	Steel hard	5.0	8.0	2.50
2200	Melted and expanding				

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.95	121.4	5.0	No bloating
1900	2.03	126.4	5.8	No bloating
2000	1.36	84.7	8.0	Slight expansion
2100	1.10	68.5	5.1	Good expansion
2200	0.76	47.3	3.6	Excellent expansion, slightly sticky

Evaluation: Excellent lightweight aggregate.

Potential Uses: Brick, excellent lightweight aggregate; possibly floor tile.

LEHIGH COUNTY

Sample Number

196-2-1

Quadrangle: Allentown 15′

Location: North side of the paved road to the east of Slatedale.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: A waste dump of relatively unweathered, medium-gray slate is readily accessible from the roadway. The fragments exposed at the surface of the waste dump are large, measuring on the average from 2 to 3 feet. The tonnage of waste slate in the area is large.

Sampled Interval: Grab sample

Type of Material: slate

Chemical Analysis:

	%
SiO_2	61.90
Al_2O_3	15.00
Fe_2O_3	1.80
FeO	4.86
CaO	2.36
MgO	1.76
K_2O	3.64
Na_2O	.90
TiO_2	.79
L.O.I.	6.98
S	.36
CO_2*	4.28
comb. H_2O	2.31
H_2O @ 120°C	.03

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	37	6
Mica	29	8
Kaolinite	20	8
C-V-Mo	4	3
Feldspar	3	3

Remarks: carbonates present

Other Tests:

pH: 6.8
Workability: slightly plastic, short
Water of plasticity %: 16.0
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown buff	Soft, crumbly	3.5	17.9	2.54
1900	Buff brown	Soft, crumbly	3.5	18.8	2.53
2000	Buff brown	Soft, crumbly	4.0	17.6	2.54
2100	Dk. brown	Steel hard	6.5	11.5	2.45
2200	Melted and expanded				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: $-\frac{1}{2} + \frac{1}{4}''$

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.88	117.1	4.0	No bloating
2000	2.01	125.2	6.4	No bloating
2100	0.50	31.2	17.7	Excellent bloating
2200	0.46	28.7	23.6	Overbloated, sticky, fragile

Evaluation: The bloating range is rather short, but with close temperature control, this material will make a good lightweight aggregate.

Potential Uses: Good lightweight aggregate.

LEHIGH COUNTY

Sample Number

196-9-1

Quadrangle: Allentown 15'

Location: Exposures on the property of the Eastern Lime Corporation northeast of Wescoesville, on the east side of the northeast extension of the Pennsylvania Turnpike.

Geologic Unit: Illinoian terminal moraine, Quaternary Age

Description: The exposures occur in a glacial moraine deposit which consists of a matrix of pale- and dark-yellow-orange clay containing fragments and boulders of shale and carbonate rocks. The rock fragments and boulders are estimated to make up about 15 to 20 per cent of the deposit. The exposures occur in an area which measures about 100 by 300 feet in plan.

Attitude of Bedding: N10E; 23E

Sampled Interval: Channel sample taken from 0 to 6 feet vertically below ground surface.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	62.90
Al_2O_3	15.60
Fe_2O_3	6.54
FeO	.46
CaO	.14
MgO	1.02
K_2O	6.65
Na_2O	.64
TiO_2	.83
L.O.I.	5.19
S	.028
CO_2	.40
comb. H_2O	4.79

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	39	8
Mica	32	8
Kaolinite	1	5
C-V-Mo	2	4
Feldspar	17	6

Other Tests:

pH: 6.3
Workability: fairly plastic and smooth, short
Water of plasticity %: 22.0
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff orange	Soft, crumbly	2.5	17.5	2.64
1900	Dk. buff orange	Very hard	4.0	16.0	2.64
2000	Brown	Steel hard	7.5	9.3	2.60
2100	Dk. brown	Steel hard	10.0	3.6	2.53
2200	Dk. brown	Expanding and melting			

Bloating test: Slight expansion

Potential Uses: Brick and tile.

LUZERNE COUNTY

Sample Number

184-6-1

Quadrangle: Wilkes-Barre 15'; White Haven 7½'

Location: Exposure about 3.8 miles north of White Haven and about 0.2 mile north of the northeastern corner of Penn Lake, along the north side of the Northeast Extension of the Pennsylvania Turnpike.

Geologic Unit: Mauch Chunk Formation, Mississippian Age

Description. Thin-bedded, gray-red shales, grading with depth into siltstones, are exposed in a roadcut. The shales, estimated to make up 70 percent of the section, break up into hackly fragments averaging about 1 to 2 inches in size. The siltstone beds are thicker, commonly ranging from 1 to 2 feet thick. The siltstone predominates in the lower part of the exposure and is estimated to make up 30 percent of the section. The exposure extends for a distance of about 350 feet along the Turnpike and is about 15 to 20 feet high.

Attitude of Bedding: N55E; 17S (maximum dip)

Sampled Interval: 24-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	65.30
Al_2O_3	17.10
Fe_2O_3	6.58
FeO	.84
CaO	.13
MgO	1.01
K_2O	3.68
Na_2O	.27
TiO_2	.85
L.O.I.	4.19
S	.016
CO_2*	.22
comb. H_2O	3.30
H_2O @ 120°C	.65

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	41	6
Mica	47	8
Kaolinite	0	2
C-V-Mo	2	2
Feldspar	1	3

Other Tests:

pH: 6.9
Workability: slightly plastic, short
Water of plasticity %: 18.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.0	16.2	2.62
1900	Brown	Soft, crumbly	5.0	13.0	2.65
2000	Brown	Steel hard	5.0	11.9	2.65
2100	Dk. red brown	Steel hard	7.5	8.4	2.62
2200	Dk. gray brown	Steel hard	10.0	1.9	2.56
2300	Expanded and melting				

Bloating Test: Negative

Potential Uses: Floor tile; possibly brick.

LUZERNE COUNTY

Sample Number

185-1-1

Quadrangle: Hazleton 15'; Hazleton 7½'

Location: Hazleton Brick Company quarry on the west side of U. S. Highway 309, about 2 miles southwest of Hazleton.

Geologic Unit: Mauch Chunk Formation, Mississippian Age

Description: Pale-reddish-brown shales, dipping gently to the north, are exposed for a stratigraphic interval of at least 15 feet in the quarry walls. The shales are overlain by red clays which are about 8 feet thick.

Sampled Interval: Grab sample from stockpile at plant

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.30
Al_2O_3	16.90
Fe_2O_3	7.12
FeO	.72
CaO	.08
MgO	.77
K_2O	4.05
Na_2O	.40
TiO_2	.95
L.O.I.	4.68
S	.01
CO_2	.26
comb. H_2O	4.30
H_2O @ 120°C	.12

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	48	7
Mica	34	8
Kaolinite	11	7
C-V-Mo	4	3
Feldspar	1	3

Remarks:

Other Tests:

pH: 6.2
Workability: slightly plastic, short
Water of plasticity %: 22.0
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff brown	Soft, crumbly	2.5	22.7	2.76
1900	Dk. buff brown	Soft, crumbly	5.0	19.8	2.75
2000	Brown	Soft, crumbly	7.5	15.2	2.72
2100	Dk. brown	Fairly hard	10.0	12.5	2.72
2200	Dk. brown	Hard	10.0	7.9	2.64
2300	Gray black	Very hard	10.0	4.0	2.52

Bloating Test: Negative

Potential Uses: Brick and tile.

LYCOMING COUNTY

Sample Number

134-1-1

Quadrangle: Williamsport 15'

Location: North side of U. S. Route 220, about 0.6 mile east of its intersection with State Route 287.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: Greenish-gray, thin-bedded shales and siltstones are exposed for a distance of about 425 feet along the highway. Fragments of weathered rock on the slope are platy to tabular in shape with sharp edges. Some fracture surfaces are iron-stained yellow orange and yellow brown. The exposure is about 40 feet high. A thin soil overburden, estimated at 1 to 2 feet, is present at the top of the exposure.

Attitude of Bedding: N80E; 30S

Sampled Interval: 20-foot channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	66.60
Al_2O_3	15.90
Fe_2O_3	4.16
FeO	2.58
CaO	.20
MgO	1.16
K_2O	3.09
Na_2O	1.04
TiO_2	.92
L.O.I.	4.30
S	.022
CO_2*	.53
comb. H_2O	3.77
H_2O @ 120°C	.47

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	45	8
Mica	35	8
Kaolinite	5	4
C-V-Mo	6	3
Feldspar	2	2

Remarks: some carbonates present

Other Tests:

pH: 6.7
Workability: not plastic, mealy, gritty
Water of plasticity %: 16.1
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	1.0	14.3	2.65
1900	Buff orange	Soft, crumbly	1.0	13.9	2.66
2000	Brown	Hard	2.0	10.9	2.65
2100	Dk. brown	Very hard	5.0	8.1	2.61
2200	Very dk. brown	Steel hard	5.0	4.0	2.43
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.34	145.8	5.1	No bloating
2000	2.26	140.8	5.6	No bloating
2100	2.04	127.1	6.1	Slight bloating
2200	1.51	94.1	5.1	Good bloating
2300	1.20	74.8	6.4	Overbloated and sticky

Evaluation: The sample is a mixture of weathered and unweathered material. The unweathered material would probably make a good lightweight aggregate by the rotary kiln process.

Potential Uses: Unweathered material would probably make good lightweight aggregate.

Remarks: Acid treatment shows small amount of calcareous material present.

MONROE COUNTY

Sample Number

215-1-1

Quadrangle: Delaware Water Gap 15'; Stroudsburg 7½'

Location: Exposure about one mile west of Arlington Heights along the recent cutoff for U. S. Route 611.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: Medium-to dark-gray, thin-bedded shales and siltstones are exposed for a distance of about 525 feet in the roadcut. The beds average about one inch in thickness. The majority of rock fragments on the slopes of the roadcut are larger than two inches with irregular, sharp edges. The height of the exposure is about 20 feet with approximately one foot of soil overburden at the top.

Attitude of Bedding: N65E; 28S

Sampled Interval: Grab sample of fragments collected along the entire exposure.

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	61.30
Al_2O_3	17.50
Fe_2O_3	1.97
FeO	4.48
CaO	1.67
MgO	1.30
K_2O	3.75
Na_2O	.87
TiO_2	.90
L.O.I.	6.24
S	.42
CO_2*	3.29
comb. H_2O	2.50
H_2O @ 120°C	.03

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	38	7
Mica	36	7
Kaolinite	16	8
C-V-Mo	2	3
Feldspar	1	3

Other Tests:

pH: 9.5
Workability: not plastic, short, mealy
Water of plasticity %: 17.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	6.0	14.7	2.63
1900	Brown	Soft, crumbly	6.0	15.3	2.62
2000	Brown	Very hard	6.0	14.5	2.63
2100	Dk. brown	Steel hard	8.0	7.0	2.52
2200	Expanded and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: $-\frac{1}{2} + \frac{1}{4}''$

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.97	122.7	8.5	No bloating
2000	1.14	71.0	14.7	Fair bloating
2100	0.85	53.0	13.8	Good bloating
2200	0.46	28.7	15.5	Overbloated, fragile and slightly sticky

Evaluation: Good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	49.6
—1/4 + 1/8	30.2
—1/8 + 16	20.2
Total	100.0

Screen analysis

Size	Percent retained
+3/8	26.9
—3/8 + 1/4	26.4
—1/4 + 8	16.1
— 8 + 16	10.8
—16 + 35	8.6
—35 + 65	5.9
—65	5.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1900	1950
Optimum	1910	1950
Maximum	1925	2005

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	116
Fired	47
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	9:00
Particle shape	Angular
Pore structure	Fine
Expansion	Good
Uniformity of firing	U
Color	gray

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.^{3}	% Abs.
—3/4 + 1/2	1.30	81.0	6.6
—1/2 + 1/4	1.46	91.0	7.6
—1/4 + 8 mesh	1.48	92.2	6.8

Screen analysis

Size	Percent retained
+3/8	56.3
—3/8 + 1/4	37.0
—1/4 + 8	5.0
— 8 + 16	.1
—16 + 35	.4
—35 + 65	.5
—65	.7
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.45
Lb/Ft^3	90
Compression (PSI)	5097
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.0

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.49
Lb/Ft^3	91
Compression (PSI)	4349
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	5.1

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.47	Bulk Sp. Gr.	1.50
Lb/Ft^3	92	Lb/Ft^3	94
Compression (PSI)	6487	Compression (PSI)	5016
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	4.9	% Abs.	5.7

Potential Uses: Good lightweight aggregate.

Remarks: Acid treatment shows a small amount of calcareous material.

MONTGOMERY COUNTY

Sample Number

197-3-1

Quadrangle: Boyertown 15'; East Greenville 7½'

Location: Exposure along State Route 29 about 1.2 miles northwest of the center of East Greenville.

Geologic Unit: Brunswick Formation, Triassic Age

Description: Thin-bedded, gray-red shales are exposed for a distance of about 400 feet along the roadway. Upon weathering, the shale breaks down into small angular fragments ranging in thickness from less than one inch up to several inches. The height of the exposure is about 12 feet with the upper foot consisting of soil overburden.

Attitude of Bedding: N40W; 25SW

Sampled Interval: Channel sample taken from 1 to 11 feet vertically below surface.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.50
Al_2O_3	14.50
Fe_2O_3	4.23
FeO	1.46
CaO	2.83
MgO	1.76
K_2O	4.10
Na_2O	1.25
TiO_2	.78
L.O.I.	6.55
S	.010
CO_2	1.46
comb. H_2O	5.09

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	34	8
Kaolinite	1	3
C-V-Mo	4	3
Feldspar	5	3

Remarks: calcite present

Other Tests:

pH: 8.1
Workability: not very plastic, fine grit, fairly short
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk. buff brown	Soft, crumbly	1.0	16.4	2.61
1900	Dk. buff brown	Soft, crumbly	1.0	16.5	2.62
2000	Brown	Very hard	1.0	13.1	2.55
2100	Dk. brown	Steel hard	5.5	3.7	2.41

Bloating Test: Negative

Potential Uses: Brick.

Remarks: Slightly effervescent, indicating $CaSO_4$ or $CaCO_3$.

MONTGOMERY COUNTY

Sample Number

208-1-1

Quadrangle: Norristown 15'; Collegeville 7½'

Location: Outcrop along the west side of State Route 29, about 0.7 mile north of the intersection of State Route 29 and U. S. Route 422 at the east edge of Collegeville.

Geologic Unit: Brunswick Formation, Triassic Age

Description: Grayish-red shales and siltstones outcrop for a distance of about 300 feet along the roadway. The shale to siltstone ratio is about 2 to 1. The shale beds weather to small fragments, commonly less than ½ inch in size. The more resistant siltstone strata make up larger fragments. The maximum height of the outcrop is about 20 feet.

Attitude of Bedding: N75W; 15N

Sampled Interval: Channel sample from upper 10 feet of exposed section

Type of Material: shales and siltstones

Chemical Analysis:

	%
SiO_2	64.20
Al_2O_3	16.50
Fe_2O_3	5.62
FeO	1.38
CaO	.40
MgO	1.82
K_2O	2.30
Na_2O	2.98
TiO_2	.93
L.O.I.	3.84
S	.008
CO_2	.15
comb. H_2O	3.69

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	8
Mica	38	8
Kaolinite	2	3
C-V-Mo	4	3
Feldspar	8	4

Other Tests:

pH: 7.9
Workability: not very plastic, short
Water of plasticity %: 19.0
% Drying shrinkage: 5.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.0	16.0	2.66
1900	Brown	Fairly hard	5.0	15.0	2.66
2000	Dk. brown	Very hard	7.5	10.9	2.63
2100	Dk. brown	Steel hard	8.0	0.6	2.18
2200	Expanded and melted				

Bloating Test: Slight expansion

Potential Uses: Possibly brick.

NORTHAMPTON COUNTY

Sample Number

205-6-1

Quadrangle: Wind Gap 15'

Location: Waste slate piles owned by the Stoddard Slate Companies, Albion Vein Slate Company, in West Pen Argyl.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Medium-gray slate fragments, ranging in size from less than one inch up to several feet in length, occur in a waste pile. The reserves of waste slate in the area are large.

Sampled Interval: Grab sample from lower third of slopes on dump

Type of Material: waste slate

Chemical Analysis:

	%
SiO_2	61.30
Al_2O_3	14.20
Fe_2O_3	2.58
FeO	3.68
CaO	3.57
MgO	1.96
K_2O	3.40
Na_2O	1.57
TiO_2	.80
L.O.I.	6.92
S	.62
CO_2	5.97
comb. H_2O	.90
H_2O @ 120°C	.05

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	35	8
Mica	31	8
Kaolinite	18	10
C-V-Mo	4	4
Feldspar	1	3

Remarks: calcite present

Other Tests:

pH: 8.0
Workability: not plastic, very short
Water of plasticity %: 15.0
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	0.5	19.2	2.66
1900	Lt. brown	Soft, crumbly	0.5	18.2	2.66
2000	Lt. brown	Hard	0.5	20.8	2.64
2100	Very dk. brown	Steel hard	2.5	14.5	2.48
2200	Expanding and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.69	105.3	10.4	No bloating
2000	1.10	68.5	11.3	Fair expansion
2100	0.77	48.0	6.4	Excellent bloating
2200	0.55	34.3	13.9	Overfired, fragile and very sticky

Evaluation: This material has a long bloating range and expands uniformly. It would make an excellent lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Poor
Particle shape	Angular & Platy
Particle thickness	Nonuniform
Uniformity	Unweathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	42.1
—1/4 + 1/8	33.4
—1/8 + 16	24.5
Total	100.0

Screen analysis

Size	Percent retained
+3/8	19.8
—3/8 + 1/4	23.7
—1/4 + 8	18.8
— 8 + 16	13.8
—16 + 35	11.1
—35 + 65	6.7
—65	6.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1910	1960
Optimum	1960	2000
Maximum	1960	2040

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	100
Fired	49
Effect of quenching	NA
Processing characteristics	Poor
Material flow	U
Point of release	10:00
Particle shape	Angular
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	U
Color	gray to black

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.^{3}	% Abs.
—3/4 + 1/2	1.37	85.4	6.3
—1/2 + 1/4	1.37	85.4	5.8
—1/4 + 8 mesh	1.32	82.2	5.0

Screen analysis

Size	Percent retained
+3/8	46.7
—3/8 + 1/4	34.4
—1/4 + 8	16.9
— 8 + 16	.9
—16 + 35	.4
—35 + 65	.3
—65	.4
Total	100.0

Concrete tests:

Bags Cement/Yd.	5	Bags Cement/Yd.	5
Bulk Sp. Gr.	1.45	Bulk Sp. Gr.	1.46
Lb/Ft^3	90	Lb/Ft^3	91
Compression (PSI)	4162	Compression (PSI)	2894
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	4.1	% Abs.	4.8

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.52	Bulk Sp. Gr.	1.53
Lb/Ft^3	95	Lb/Ft^3	96
Compression (PSI)	4495	Compression (PSI)	4430
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	5.0	% Abs.	5.5

Potential Uses: Good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated that this material would make an excellent lightweight aggregate; however, subsequent rotary kiln tests on a bulk sample indicated that it should be downgraded to a good lightweight aggregate.

The material is slightly effervescent, indicating $CaSO_4$ or $CaCO_3$.

NORTHAMPTON COUNTY

Sample Number

205-8-2

Quadrangle: Wind Gap 15'

Location: Exposure on the east side of State Route 512 about one mile southeast of Moorestown.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Dark-gray shale which weathers to a moderate-yellow-brown color and exhibits a well-developed cleavage is exposed along the roadway. The cleavage planes commonly occur about ⅛ inch apart. The exposure is about 15 feet high and extends for a distance of about 1000 feet along the road.

Attitude of Bedding: N60E; 25SE

Sampled Interval: Channel sample taken from 1 to 11 feet vertically below surface

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.40
Al_2O_3	15.50
Fe_2O_3	5.69
FeO	1.54
CaO	.12
MgO	1.83
K_2O	3.92
Na_2O	.75
TiO_2	.86
L.O.I.	5.33
S	.022
CO_2	.48
comb. H_2O	4.85

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	8
Mica	26	8
Kaolinite	15	8
C-V-Mo	12	5
Feldspar	2	4

Remarks: some montmorillonite (Mo) or vermiculite (V) present

Other Tests:

pH: 7.3
Workability: not plastic, very short
Water of plasticity %: 23.0
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff brown	Soft, crumbly	0.5	21.3	2.66
1900	Buff brown	Fairly hard	0.5	18.3	2.64
2000	Dk. brown	Steel hard	5.0	11.1	2.58
2100	Very dk. brown	Steel hard	7.5	3.8	2.41
2200	Very dk. brown	Expanding and melting			

Bloating Test: Slight expansion

Potential Uses: Possibly brick.

NORTHAMPTON COUNTY

Sample Number

215-4-1

Quadrangle: Delaware Water Gap 15'; Stroudsburg 7½'

Location: Waste slate dump on property of Capitol Slate Quarry in East Bangor.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Medium-gray slate fragments ranging in size from less than an inch up to about six feet in length occur in a waste dump. A few fragments contain small amounts of secondary quartz and/or silty layers. The reserves in these dumps are large and probably represent between 60 to 85 per cent of the slate taken from the quarry.

Sampled Interval: Grab sample from slopes of dump

Type of Material: waste slate

Chemical Analysis:

	%
SiO_2	61.10
Al_2O_3	14.40
Fe_2O_3	2.69
FeO	3.52
CaO	3.23
MgO	2.03
K_2O	3.48
Na_2O	1.33
TiO_2	.74
L.O.I.	7.48
S	.86
CO_2	2.86
comb. H_2O	4.55
H_2O @ 120°C	.07

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	34	8
Kaolinite	13	7
C-V-Mo	7	4
Feldspar	3	3

Other Tests:

pH: 8.9
Workability: not plastic, very short
Water of plasticity %: 16.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Soft, crumbly	2.5	17.6	2.61
1900	Lt. brown	Soft, crumbly	2.5	16.9	2.59
2000	Lt. brown	Soft, crumbly	2.5	17.2	2.57
2100	Very dk. brown	Steel hard	2.5	7.8	2.12
2200	Melting and expanding				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.72	107.2	7.5	No bloating
1900	1.80	112.1	5.7	No bloating
2000	1.21	75.4	9.9	Fair expansion
2100	0.59	36.8	18.3	Excellent bloating
2200	0.53	33.0	17.6	Overbloated, fragile, slightly sticky

Evaluation: The bloating range is rather short but with close temperature control this material would make a good lightweight aggregate.

Potential Uses: Good lightweight aggregate.

NORTHAMPTON COUNTY

Sample Number

215-7-2

Quadrangle: Delaware Water Gap 15'; Bangor 7½'

Location: Exposure along U. S. Route 611, about 1.4 miles southwest of the town of Mt. Pleasant.

Geologic Unit: Martinsburg Formation, Ordovician Age

Description: Light-gray to medium-dark-gray, thin-bedded shale is exposed for a distance of about 450 feet. "Zebra" banding occurs in the southern part of the exposure. The bands range from ¼ to 1 inch in width and are pale yellow brown, light gray, or medium gray. The shale fragments on the slope of the roadcut are very platy and measure up to about 3 inches in length. The height of the exposure is about 10 feet.

Attitude of Bedding: N70E; 30N

Sampled Interval: Grab sample; small sample taken every five feet along entire exposure

Type of Material: shale

Chemical Analysis:

	%
SiO_2	65.50
Al_2O_3	15.55
Fe_2O_3	5.29
FeO	1.37
CaO	.33
MgO	1.60
K_2O	3.86
Na_2O	.73
TiO_2	.77
L.O.I.	4.96
S	.04
CO_2*	1.35
comb. H_2O	3.53
H_2O @ 120°C	.04

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	38	8
Mica	42	8
Kaolinite	8	5
C-V-Mo	3	2
Feldspar	1	3

Remarks: carbonates present

Other Tests:

pH: 9.0
Workability: not plastic, short and mealy
Water of plasticity %: 16.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	5.0	15.6	2.45
1900	Dk. buff brown	Soft, crumbly	5.5	15.6	2.44
2000	Dk. buff brown	Very hard	5.5	13.5	2.37
2100	Very dk. brown	Steel hard	7.0	7.4	2.30
2200	Very dk. brown	Steel hard	7.0	9.4	2.27
2300	Expanded and melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Poor (platy) Particle size: —½ + ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.75	109.0	8.3	No bloating
2000	1.55	96.6	7.4	No bloating
2100	1.02	63.5	6.9	Good bloating
2200	0.72	44.9	6.4	Slightly overbloated, slightly sticky

Evaluation: The composition of this material is not uniform. The light-colored layers are highly siliceous. Good expansion occurs in the darker material which would make a good lightweight aggregate.

Potential Uses: Good lightweight aggregate (darker material).

Remarks: Acid treatment shows a small amount of calcareous material.

NORTHUMBERLAND COUNTY

Sample Number

146-4-4

Quadrangle: Millersburg 15'; Dalmatia 7½'

Location: Exposure along the north side of State Route 14 about 1.3 miles northwest of Malta.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: An exposure of dark-gray shale, about 15 feet high, extends for several hundred feet along the road. Upon impact, the shale breaks into pencil-shaped fragments which measure up to about six inches in length. The pencil-shape is probably due to the control of intersecting cleavages. The weathered surfaces of the shale are commonly yellow-orange.

Attitude of Bedding: None recorded

Sampled Interval: Channel sample taken from surface down through 10 stratigraphic feet

Type of Material: shale

Chemical Analysis:

	%
SiO_2	63.00
Al_2O_3	17.60
Fe_2O_3	4.75
FeO	2.48
CaO	.07
MgO	1.05
K_2O	3.70
Na_2O	.90
TiO_2	1.01
L.O.I.	5.42
S	.02
CO_2	2.42
comb. H_2O	2.59
H_2O @ 120°C	.41

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	36	8
Mica	50	10
Kaolinite	1	3
C-V-Mo	1	3
Feldspar	1	3

Other Tests:

pH: 5.1
Workability: not plastic, short and gritty
Water of plasticity %: 21.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown buff	Soft, crumbly	6.0	12.1	2.59
1900	Brown buff	Soft, crumbly	6.0	12.8	2.54
2000	Lt. brown	Fairly hard	6.5	10.1	2.55
2100	Med. brown	Very hard	6.5	6.6	2.50
2200	Dk. brown	Steel hard	9.0	3.9	2.39
2300	Dk. brown	Steel hard	Exp.	2.6	2.17

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.74	108.4	7.9	No bloating
1900	1.45	90.3	7.8	Slight bloating
2000	1.21	75.4	8.5	Fair bloating
2100	0.75	59.2	7.5	Good bloating
2200	0.68	42.4	10.8	Overbloated and sticky

Evaluation: Good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Fair
Particle shape	Angular & Elongated
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	53.0
—1/4 + 1/8	32.1
—1/8 + 16	14.9
Total	100.0

Screen analysis

Size	Percent retained
+3/8	10.3
—3/8 + 1/4	39.9
—1/4 + 8	24.2
— 8 + 16	11.1
—16 + 35	7.1
—35 + 65	3.4
—65	4.0
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1920	1970
Optimum	1920	1960
Maximum	1940	2020

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	97
Fired	71
Effect of quenching	NA
Processing characteristics	Fair
Material flow	U
Point of release	9:00
Particle shape	Angular
Pore structure	Fine
Expansion	Poor
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	ASG	Lb/Ft.³	% Abs.
—3/4 + 1/2	2.20	137.1	2.3
—1/2 + 1/4	2.04	127.1	1.4
—1/4 + 8 mesh	1.80	112.1	0.9

Screen analysis

Size	Percent retained
+3/8	25.6
—3/8 + 1/4	49.1
—1/4 + 8	23.0
— 8 + 16	1.6
—16 + 35	.2
—35 + 65	.2
—65	.3
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.86
Lb/Ft³	116
Compression (PSI)	5747
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	6.9

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.90
Lb/Ft³	118
Compression (PSI)	5479
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	8.7

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.94	Bulk Sp. Gr.	1.95
Lb/Ft^3	121	Lb/Ft^3	121
Compression (PSI)	7682	Compression (PSI)	6975
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	7.8	% Abs.	9.9

Potential Uses: Brick.

Remarks: The bloating tests (quick-firing) indicated that this material would make a good lightweight aggregate, but further tests in a laboratory-sized rotary kiln on a bulk sample of this material indicated a poor potential for lightweight aggregate.

NORTHUMBERLAND COUNTY

Sample Number

146-5-2

Quadrangle: Millersburg 15'; Pillow 7½'

Location: Exposure on the east side of a north-south trending roadway about 2.5 miles west of Uniontown.

Geologic Unit: Marine beds, Susquehanna Group, Devonian Age

Description: Olive-green shales interbedded with some siltstones occur in a road exposure. The rocks weather yellow-orange and brown. Mica flakes are common along the fractures in the siltstone beds. The intersection of bedding and cleavage indicates the beds are not overturned.

Attitude of Bedding: N75E; 55S

Sampled Interval: Channel sample from 25 feet of stratigraphic section

Type of Material: shale

Chemical Analysis:

	%
SiO_2	64.10
Al_2O_3	16.45
Fe_2O_3	6.41
FeO	1.61
CaO	.15
MgO	.95
K_2O	3.48
Na_2O	.82
TiO_2	1.08
L.O.I.	4.89
S	.012
CO_2	.33
comb. H_2O	4.56

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	8
Mica	46	10
Kaolinite	0	2
C-V-Mo	3	3
Feldspar	0	2

Remarks: little or no chlorite (C) present

Other Tests:

pH: 7.1
Workability: not very plastic, short and mealy
Water of plasticity %: 18.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff-brown	Soft, crumbly	2.5	17.9	2.73
1900	Dk. buff brown	Soft, crumbly	5.0	16.2	2.71
2000	Med. brown	Fairly hard	5.0	11.3	2.66
2100	Dk. brown	Hard	7.5	9.1	2.64
2200	Dk. brown	Very hard	7.5	5.5	2.51
2300	Dk. brown	Steel hard	7.5	5.2	2.51
*2000		Very hard	1.0	7.4	2.67
*2050		Steel hard	3.8	3.2	2.59

* Additional firing data: miniature pressed brick with 2 hour soak.

Bloating Test: Negative

Potential Uses: Brick.

NORTHUMBERLAND COUNTY

Sample Number

146-5-3

Quadrangle: Millersburg 15'; Dalmatia 7½'

Location: Exposure on the east side of a road trending generally northwest-southeast about 1.5 miles northeast of Malta.

Geologic Unit: Catskill Formation, Devonian Age

Description: Pale-reddish-brown shales with some interbedded siltstones occur in a road exposure. The siltstones are harder and more resistant to weathering than the shales. The intersection of bedding and cleavage indicates the beds are not overturned. The exposure is about 8 feet high with a thin soil overburden at the top.

Attitude of Bedding: N65E; 46S

Sampled Interval: 20-foot channel sample from the north end of the exposure

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	65.80
Al_2O_3	16.45
Fe_2O_3	5.39
FeO	1.28
CaO	.30
MgO	1.56
K_2O	3.10
Na_2O	.93
TiO_2	.93
L.O.I.	4.23
S	.006
CO_2	.26
comb. H_2O	3.41
H_2O @ 120°C	.56

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	46	8
Mica	38	10
Kaolinite	1	3
C-V-Mo	3	2
Feldspar	3	3

Other Tests:

pH: 7.1
Workability: not plastic, short and mealy
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Dk buff brown	Soft, crumbly	2.5	19.0	2.73
1900	Dk. buff brown	Soft, crumbly	2.5	17.0	2.71
2000	Med. brown	Fairly hard	4.5	12.5	2.67
2100	Dk. brown	Hard	6.5	9.0	2.64
2200	Dk. brown	Steel hard	6.5	4.4	2.51
2300	Dk. brown	Steel hard	6.5	6.0	2.53
*2000		Steel hard	2.7	5.7	2.65
*2050		Steel hard	4.0	2.3	2.58

* Additional firing data: miniature pressed brick with 2 hour soak.

Bloating Test: Negative

Potential Uses: Brick.

NORTHUMBERLAND COUNTY

Sample Number

155-8-1

Quadrangle: Shamokin 15'

Location: Bear Valley stripping located on the north flank of Mahoning Mountain, about 3.5 miles southwest of Shamokin and about 1.5 miles northeast of West Cameron.

Geologic Unit: Post-Pottsville rocks, Pennsylvanian Age

Description: Medium- to medium-dark-gray underclay to either the (No. 8) or (No. 8½) coal bed of the Mammoth horizon is exposed in the stripping. The underclay measures 3 feet but its base is not exposed so that this figure represents a minimum thickness. The clay breaks up into tabular and pencil-shaped fragments that measure up to 6 inches in length. The stripping is within the lower rank anthracite area.

Attitude of Bedding: Beds dip about 40 degrees to the north

Sampled Interval: Three-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.20
Al_2O_3	25.70
Fe_2O_3	.87
FeO	.76
CaO	.02
MgO	.39
K_2O	4.03
Na_2O	.29
TiO_2	1.01
L.O.I.	7.71
S	.20
CO_2*	4.66
comb. H_2O	3.05
H_2O @ 120°C	.36

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	6
Mica	48	8
Kaolinite	8	5
C-V-Mo	1	2
Feldspar	0	2

Remarks: carbonates present

Other Tests:

pH: 4.3
Workability: not plastic, short, gritty
Water of plasticity %: 15.8
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. sandy buff	Soft, crumbly	0.5	13.5	2.55
1900	Lt. sandy buff	Soft, crumbly	0.5	14.9	2.57
2000	Lt. sandy buff	Very hard	4.0	13.5	2.56
2100	Lt. buff	Very hard	4.0	10.6	2.53
2200	Lt. buff	Very hard	5.5	7.8	2.51
2300	Lt. buff	Very hard	6.0	5.5	2.49

Bloating Test: Negative

Potential Uses: None

PERRY COUNTY

Sample Number

127-4-1

Quadrangle: Loysville 15'; Spruce Hill 7½'

Location: Quarry located about 1.2 miles north of Kistler, along the south side of State Route 850.

Geologic Unit: Rose Hill Formation, Clinton Group, Middle Silurian Age

Description: Medium-gray and pale-yellow-brown, thin-bedded shales with a few interbeds of siltstones are exposed in a quarry. The beds range in thickness from less than one inch up to about 6 inches. Some shale beds contain fossils. Concentric-shaped structures resembling "storm rollers" occur in places. The quarry is about 35 feet high and extends for a distance of 200 feet. A soil overburden from 2 to 3 feet thick occurs at the surface.

Attitude of Bedding: N55E; 37SE

Sampled Interval: Grab sample from about 70 feet of stratigraphic section of the exposed Rose Hill Formation

Type of Material: shale and siltstones

Chemical Analysis:

	%
SiO_2	62.10
Al_2O_3	17.75
Fe_2O_3	5.58
FeO	1.68
CaO	.36
MgO	1.27
K_2O	4.15
Na_2O	.70
TiO_2	.96
L.O.I.	5.42
S	.02
CO_2	.44
comb. H_2O	4.67
H_2O @ 120°C	.31

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	43	10
Kaolinite	0	2
C-V-Mo	3	2
Feldspar	1	3

Other Tests:

pH: 7.9
Workability: not plastic, short, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff brown	Soft, crumbly	4.0	15.5	2.69
1900	Brown	Soft, crumbly	5.0	13.3	2.67
2000	Brown	Hard	5.0	10.8	2.66
2100	Dk. brown	Steel hard	5.5	7.6	2.61
2200	Gray black	Steel hard	Exp.	7.7	2.08

Bloating Test: Slight bloating

Potential Uses: Floor tile and possibly brick.

PERRY COUNTY

Sample Number

127-4-3

Quadrangle: Loysville 15'; Andersonburg 7½'

Location: Exposure on the east side of a road leading south-southeast from State Route 274 at the town of Cisna Run.

Geologic Unit: Upper member, Wills Creek Formation, Silurian Age

Description: Light-olive-gray and medium-gray, thin-bedded and interbedded calcareous shales and siltstones of the Upper member of the Wills Creek Formation are exposed along the roadway. The beds range in thickness from less than ½ inch up to 5 inches and weather tan or grayish yellow in color. The shale beds break into very thin plates but the siltstones break into irregular, tabular-shaped fragments. The rocks are exposed for a distance of about 300 feet along the rock cut. The height of the exposure is about 15 feet, capped by a cover of overburden about two feet deep.

Attitude of Bedding: NE-SW; 33NW

Sampled Interval: Grab samples from the upper half of the exposed stratigraphic section

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	46.00
Al_2O_3	10.20
Fe_2O_3	1.88
FeO	1.82
CaO	16.75
MgO	1.66
K_2O	3.08
Na_2O	.25
TiO_2	.48
L.O.I.	17.88
S	.024
CO_2*	14.49
comb. H_2O	2.98
H_2O @ 120°C	.39

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	32	6
Mica	47	8
Kaolinite	0	2
C-V-Mo	3	2
Feldspar	2	2

Remarks: carbonates present

Other Tests:

pH: 9.1
Workability: not plastic, short, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff	Soft, crumbly	1.0	26.3	2.52
1900	Buff tan	Soft, crumbly	1.0	26.3	2.48
2000	Buff tan	Soft, crumbly	1.0	25.4	2.46
2100	Buff orange	Soft, crumbly	1.0	23.9	2.42
2200	Melted				

Bloating Test: Slight bloating

Potential Uses: None

PERRY COUNTY

Sample Number

137-4-1

Quadrangle: New Bloomfield 15'; Newport 7½'

Location: Quarry located about 0.8 mile southeast of the center of New Bloomfield on the north side of an unimproved road which leads eastward from State Highway 34.

Geologic Unit: Mahantango Formation, Hamilton Group, Devonian Age

Description: Olive-gray shale beds, ranging in thickness from ¼ to 11 inches, are exposed in the quarry wall. The average thickness of the beds is approximately one inch. The colors of weathered shale are various shades of tan, gray orange and blue gray. The shale breaks readily into irregular, tabular-shaped fragments which average several inches in length. Concentric-shaped structures resembling "mudballs," measuring up to 6 feet, occur in moderate number. The quarry exposure extends for a distance of about 375 feet along the road. Its height reaches 25 feet. The overburden at the surface reaches a maximum of two feet in thickness.

Attitude of Bedding: N58E; 75NW (overturned)

Sampled Interval: Grab sample over entire length of exposure. Fragments collected every hammer length in a direction normal to the beds

Type of Material: shale

Chemical Analysis:

	%
SiO_2	61.50
Al_2O_3	18.60
Fe_2O_3	6.10
FeO	1.44
CaO	.19
MgO	.96
K_2O	3.60
Na_2O	.45
TiO_2	.94
L.O.I.	6.20
S	.02
CO_2	.66
comb. H_2O	4.70
H_2O @ 120°C	.84

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	6
Mica	42	8
Kaolinite	0	2
C-V-Mo	4	3
Feldspar	1	3

Other Tests:

pH: 7.2
Workability: not plastic, short, hardens on standing
Water of plasticity %: 21.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	4.0	16.9	2.52
1900	Dk. buff orange	Soft, crumbly	4.0	13.2	2.50
2000	Dk. buff orange	Soft, crumbly	5.0	10.0	2.47
2100	Med. brown	Steel hard	7.0	4.5	2.44
2200	Dk. brown	Steel hard	10.0	2.0	2.36
2300	Gray black	Steel hard	Exp.	1.4	2.05

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	2.26	140.8	3.6	No bloating
1900	2.05	127.7	3.5	No bloating
2000	1.72	107.2	5.0	No bloating
2100	1.50	93.5	7.2	Slight bloating
2200	1.29	80.4	5.2	Fair bloating

Evaluation: The bloating temperature is too high for lightweight aggregate. Further testing on another sample from this location is recommended.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	48.3
—1/4 + 1/8	31.6
—1/8 + 16	20.1
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	16.1
—3/8 + 1/4	30.5
—1/4 + 8	20.0
— 8 + 16	12.7
—16 + 35	8.9
—35 + 65	6.2
—65	5.6
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1995	2045
Optimum	1985	2000
Maximum	2050	2130

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	106
Fired	56
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular & Rounded
Pore structure	Medium, Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.55	96.6	6.2
—1/2 + 1/4	1.47	91.6	6.8
—1/4 + 8 mesh	1.68	104.7	7.4

Screen analysis

Size	*Percent retained*
+3/8	27.6
—3/8 + 1/4	55.2
—1/4 + 8	14.1
— 8 + 16	1.3
—16 + 35	.6
—35 + 65	.5
—65	.7
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.52
Lb/Ft^3	94
Compression (PSI)	4203
Color (colorimeter)	41
Cure	Autoclave
% Abs.	6.6

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.53
Lb/Ft^3	95
Compression (PSI)	4137
Color (colorimeter)	38
Cure	28 Day Steam
% Abs.	6.2

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.60	Bulk Sp. Gr.	1.61
Lb/Ft^3	100	Lb/Ft^3	101
Compression (PSI)	5991	Compression (PSI)	4137
Color (colorimeter)	42	Color (colorimeter)	44
Cure	Autoclave	Cure	28 Day Steam
% Abs.	8.8	% Abs.	8.9

Potential Uses: Good lightweight aggregate; possibly brick and tile.

Remarks: The results obtained from the bloating tests (quick-firing) indicated that the bloating temperature was high for lightweight aggregate and further testing was recommended. Rotary kiln tests on a bulk sample were therefore made and the results indicated the material would make a good lightweight aggregate.

PIKE COUNTY

Sample Number

213-4-1

Quadrangle: Hawley 15′

Location: Southeast side of State Route 507 on the south side of Lake Wallenpaupack, about 0.6 mile southwest of Paupack Church.

Geologic Unit: Catskill Formation, Susquehanna Group, Devonian Age

Description: Grayish-red, thin-bedded shales and siltstones are exposed along the roadway. The thickest bed measures 3 inches. The shale breaks into platy fragments; the siltstone into tabular fragments. A minor amount of yellow-brown staining occurs on fracture surfaces. The exposure extends for a distance of 450 feet along the roadway and is about 12 feet high.

Attitude of Bedding: Essentially horizontal bedding

Sampled Interval: 12-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.10
Al_2O_3	18.80
Fe_2O_3	5.80
FeO	2.43
CaO	.08
MgO	1.08
K_2O	4.23
Na_2O	.49
TiO_2	.99
L.O.I.	3.95
S	.016
CO_2*	.22
comb. H_2O	3.65
H_2O @ 120°C	.06

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	32	8
Mica	50	10
Kaolinite	5	5
C-V-Mo	2	2
Feldspar	1	2

Other Tests:

pH: 6.8
Workability: not plastic, short, fine grit
Water of plasticity %: 19.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.0	15.4	2.61
1900	Brown	Soft, crumbly	5.0	15.6	2.63
2000	Brown	Very hard	7.5	14.5	2.64
2100	Rich brown	Steel hard	7.5	11.1	2.62
2200	Very dk. brown gray	Steel hard	10.0	2.8	2.48
2300	Very dk. brown gray	Steel hard	Exp.	1.0	2.12

Bloating Test: Negative

Potential Uses: Brick and floor tile.

PIKE COUNTY

Sample Number

233-4-1

Quadrangle: Port Jervis 15'; Port Jervis South 7½'

Location: Quarry exposure about 0.5 mile southwest of the center of Matamoras near the intersection of Mountain Avenue and Stark Drive.

Geologic Unit: Hamilton Group, Devonian Age

Description: Medium- to dark-gray, massive-bedded shales and siltstones are exposed in a quarry. The rock breaks into hackly fragments that range from less than an inch to more than six inches in length. Siderite nodules are common in some beds. The quarry extends for a distance of more than 2500 feet and is bounded on the north by a steep wall that is about 300 feet high.

Attitude of Bedding: N27E; 21NW

Sampled Interval: Grab sample made up of fragments collected every 10 feet along base of slope for a distance of 300 feet.

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	66.90
Al_2O_3	15.70
Fe_2O_3	2.74
FeO	4.10
CaO	.20
MgO	1.04
K_2O	3.02
Na_2O	.95
TiO_2	.92
L.O.I.	4.41
S	.016
CO_2*	1.32
comb. H_2O	2.66
H_2O @ 120°C	.41

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	41	8
Mica	37	8
Kaolinite	12	7
C-V-Mo	1	3
Feldspar	1	3

Other Tests:

pH: 7.8
Workability: not plastic, short, fine grit
Water of plasticity %: 18.0
% Drying shrinkage: 4.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	4.5	15.0	2.33
1900	Brown	Hard	5.0	14.6	2.47
2000	Brown	Very hard	5.0	11.1	2.47
2100	Rich brown	Steel hard	8.0	5.1	2.42
2200	Very dk. brown	Steel hard	10.0	2.0	2.38
2300	Very dk. brown	Steel hard	Exp.	3.3	1.50

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.82	113.4	6.4	No bloating
2000	1.60	99.7	7.9	No bloating
2100	1.24	77.3	10.3	Fair bloating
2200	0.76	47.3	18.7	Good bloating, slightly sticky

Evaluation: Fair lightweight aggregate material.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	54.6
—1/4 + 1/8	27.5
—1/8 + 16	17.9
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	22.3
—3/8 + 1/4	31.9
—1/4 + 8	16.1
— 8 + 16	10.5
—16 + 35	7.6
—35 + 65	5.3
—65	6.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1950	2000
Optimum	1950	2000
Maximum	1980	2060

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	114
Fired	58
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	11:00
Particle shape	Angular & Rounded
Pore structure	Fine
Expansion	Good
Uniformity of firing	U
Color	Lt. br. to gray

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	1.49	92.8	10.7
—1/2 + 1/4	1.63	101.5	7.9
—1/4 + 8 mesh	1.52	94.7	7.4

Screen analysis

Size	*Percent retained*
+3/8	33.2
—3/8 + 1/4	44.3
—1/4 + 8	19.1
— 8 + 16	2.2
—16 + 35	.4
—35 + 65	.3
—65	.5
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.57
Lb/Ft^3	97
Compression (PSI)	5853
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.3

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.50
Lb/Ft^3	93
Compression (PSI)	4032
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	5.7

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.59	Bulk Sp. Gr.	1.60
Lb/Ft^3	99	Lb/Ft^3	100
Compression (PSI)	7227	Compression (PSI)	4747
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	4.9	% Abs.	6.3

Potential Uses: Brick, good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated that this material would make a fair lightweight aggregate; however, subsequent rotary kiln tests on a bulk sample indicated it should be upgraded to a good lightweight aggregate material.

SCHUYLKILL COUNTY

Sample Number

166-4-2

Quadrangle: Pine Grove 15'; Pine Grove 7½'

Location: Pit exposure about 0.5 mile north-northeast of the town of Lorberry. The pit is about 400 feet southwest of the paved road connecting Lorberry and Joliett.

Geologic Unit: Pottsville Group, Pennsylvanian Age

Description: Gray clay horizon is exposed in the bottom of a prospect pit which is 6½ feet deep. The thickness of the clay is between 2 to 3 feet at this locality.

Sampled Interval: Grab sample taken from clay from 5 to 7 feet below surface

Type of Material: clay

Chemical Analysis:

	%
SiO_2	61.40
Al_2O_3	25.20
Fe_2O_3	.61
FeO	.61
CaO	.02
MgO	.43
K_2O	3.17
Na_2O	.48
TiO_2	1.14
L.O.I.	6.93
S	.008
CO_2	.51
comb. H_2O	6.42

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	35	10
Mica	34	7
Kaolinite	31	12
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 5.2
Workability: plastic, smooth for long working
Water of plasticity %: 27.0
% Drying shrinkage: 2.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. pink	Soft, crumbly	2.5	22.0	2.49
1900	Lt. pink	Soft, crumbly	4.0	20.7	2.51
2000	Lt. pink	Fairly hard	5.0	16.8	2.51
2100	Very lt. tan	Hard	9.0	9.1	2.48
2200	Very lt. tan gray	Very hard	12.5	4.2	2.45
2300	Lt. gray tan	Steel hard	13.5	1.8	2.40

Bloating Test: Negative **Pyrometric-cone equivalent:** 28-29

Potential Uses: Light color pottery, artware, drain tile, chimney flue tile; possibly low-duty refractories, decorative brick.

SCHUYLKILL COUNTY

Sample Number

175-7-1

Quadrangle: Mahanoy 15'; Shenandoah 7½'

Location: Waste pile from coal mining operations located on property of the Gilberton Lawrence Fuels, Inc., on the east side of State Route 924, about 0.1 mile south of Maizeville.

Geologic Unit: Pottsville Group, Pennsylvanian Age

Description: Waste pile consists of a mixture of shales, siltstones, sandstones and coal. The dimensions of the waste pile are approximately 800 x 1100 x 80 feet.

Sampled Interval: Grab sample collected on west side of waste pile

Type of Material: shale, siltstone, sandstone and coal

Chemical Analysis:

	%
SiO_2	54.00
Al_2O_3	15.45
Fe_2O_3	3.19
FeO	2.15
CaO	.07
MgO	.57
K_2O	3.22
Na_2O	.50
TiO_2	1.05
L.O.I.	19.75
S	.13
C	11.74
comb. H_2O	8.00

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	8
Mica	44	8
Kaolinite	11	6
C-V-Mo	2	2
Feldspar	1	2

Other Tests:

pH: 4.8
Workability: not plastic, short and gritty
Water of plasticity %: 18.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Too crumbly for properties				
1900	Too crumbly for properties				
2000	Too crumbly for properties				
2100	Red brown	Fairly hard	4.0	21.7	2.41
2200	Brown	Hard	5.0	19.0	2.42
2300	Dk. gray	Hard	9.0	13.1	2.24

Bloating Test: Negative

Potential Uses: None

SCHUYLKILL COUNTY

Sample Number

176-1-1

Quadrangle: Pottsville 15'; Pottsville 7½'

Location: Waste pile alongside the east side of U. S. Highway 122, about 0.5 mile north of St. Clair.

Geologic Unit: Post-Pottsville Formation, Pennsylvanian Age

Description: Waste pile consists of a mixture of shales, siltstones, sandstones and coal from coal mining operations.

Sampled Interval: Grab sample from waste pile

Type of Material: mixture of shale, siltstone, sandstone and coal

Chemical Analysis:

	%
SiO_2	46.62
Al_2O_3	15.34
Fe_2O_3	.73
FeO	1.20
CaO	.06
MgO	.45
K_2O	2.42
Na_2O	.31
TiO_2	1.20
L.O.I.	31.66
S	.29
CO_2*	2.60
comb. H_2O	6.59
H_2O @ 120°C	1.31

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	10
Mica	50	10
Kaolinite	0	3
C-V-Mo	0	2
Feldspar	0	2

Remarks: carbonates, sulfides (?) and pyrophyllite (?)

Potential Uses: None

SCHUYLKILL COUNTY

Sample Number

176-2-3

Quadrangle: Pottsville 15'; Orwigsburg 7½'

Location: Coal operation about 0.7 mile northwest of Middleport.

Geologic Unit: Post-Pottsville Formation, Pennsylvanian Age

Description: The sampled material consists of a mixture of shale, siltstone, sandstone and off-grade coal that was separated as waste at a coal mining operation. The waste is used in the manufacture of lightweight aggregate.

Attitude of Bedding: None

Sampled Interval: Grab sample from stockpile at Lehigh Materials Company plant near Tamaqua

Type of Material: mixture of shale, siltstone, sandstone and coal

Chemical Analysis:

	%
SiO_2	51.40
Al_2O_3	21.20
Fe_2O_3	1.48
FeO	1.24
CaO	.12
MgO	.62
K_2O	3.48
Na_2O	.68
TiO_2	1.30
L.O.I.	18.44
S	.20
CO_2*	4.29
comb. H_2O	.30
H_2O @ 120°C	1.60

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	8
Mica	52	10
Kaolinite	3	3
C-V-Mo	0	2
Feldspar	0	2

Remarks: carbonates and biotite or phlogopite present

Potential Uses: Could probably be used in sintering shales for lightweight aggregate.

SCHUYLKILL COUNTY

Sample Number

176-5-2

Quadrangle: Pottsville 15'; Auburn 7½'

Location: Auburn Brick Company quarry in the southwest corner of Auburn.

Geologic Unit: Hamilton Group, Devonian Age

Description: Dark-gray, soft shales are exposed in a quarry that is presently more than 30 feet deep. Upon weathering, the exposed surfaces of the shale become gray orange and brown in color.

Attitude of Cleavage: N35-60E; 38-50N

Sampled Interval: 30-foot channel sample taken from the southeastern corner of the quarry

Type of Material: shale

Chemical Analysis:

	%
SiO_2	59.10
Al_2O_3	20.00
Fe_2O_3	6.34
FeO	.61
CaO	.02
MgO	.67
K_2O	4.54
Na_2O	.58
TiO_2	.99
L.O.I.	7.08
S	.026
CO_2	2.16
comb. H_2O	4.92

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	37	8
Mica	52	10
Kaolinite	0	3
C-V-Mo	1	2
Feldspar	0	3

Other Tests:

pH: 5.55
Workability: fairly plastic, smooth, fairly long working
Water of plasticity %: 24.0
% Drying shrinkage: 3.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Buff brown	Soft, crumbly	4.0	20.4	2.73
1900	Buff brown	Soft, crumbly	5.0	17.0	2.71
2000	Brown red	Fairly hard	7.5	10.3	2.63
2100	Med. brown (mottled)	Very hard	10.0	6.4	2.60
2200	Dk. brown	Steel hard	10.5	3.4	2.51
2300	Expanded and melted				

Bloating Test: Negative

Potential Uses: Brick and tile.

SCHUYLKILL COUNTY

Sample Number

185-7-2A

Quadrangle: Hazleton 15'; Tamaqua 7½'

Location: Greenwood Coal Mining operations about 1.5 miles northeast of Tamaqua.

Geologic Unit: Post-Pottsville Formation, Pennsylvanian Age

Description: A mixture of shale, sandstone and coal, which is "waste" from the Greenwood Coal Mining operation, is being utilized as lightweight aggregate material by the Lehigh Materials Company at Tamaqua, Pennsylvania.

Attitude of Bedding: None

Sampled Interval: Grab sample from stockpile at Lehigh Materials Company plant

Type of Material: mixture of shale, sandstone and coal

Chemical Analysis:

	%
SiO_2	47.80
Al_2O_3	15.45
Fe_2O_3	2.29
FeO	1.22
CaO	.08
MgO	.48
K_2O	2.60
Na_2O	.31
TiO_2	1.16
L.O.I.	28.57
S	.52
CO_2*	.30
comb. H_2O	2.95
H_2O @ 120°C	1.01

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	35	8
Mica	51	10
Kaolinite	2	3
C-V-Mo	1	3
Feldspar	0	2

Remarks: carbonates, zeolites, natrojarosite?, and pyrophyllite? and biotite or phlogopite present

Potential Uses: Could probably be used in sintering shales for lightweight aggregate.

SOMERSET COUNTY

Sample Number

49-9-1

Quadrangle: Confluence 15'

Location: Exposure along the southeast side of the Baltimore and Ohio Railroad tracks, about 0.5 mile northeast of Ursina.

Geologic Unit: Brush Creek shale, Conemaugh Formation, Pennsylvanian Age

Description: Dark-gray, thin-bedded, carbonaceous shale is exposed for a distance of more than 500 feet along a railroad cut. Fossils which indicate a marine environment are present in the shale. A few beds of silty shale and some beds containing siderite nodules, usually concentrated at the bedding planes, occur in the section. Upon impact, the shale usually breaks into chip-sized fragments. Brush Creek coal occurs below this shale horizon but is not exposed in this cut.

Attitude of Bedding: N20E; 3W

Sampled Interval: 12-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	52.60
Al_2O_3	18.87
Fe_2O_3	3.69
FeO	3.60
CaO	4.10
MgO	1.76
K_2O	2.40
Na_2O	.45
TiO_2	.82
L.O.I.	11.66
S	.52
CO_2	3.96
comb. H_2O	6.62
H_2O @ 120°C	1.03

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	6
Mica	35	8
Kaolinite	9	5
C-V-Mo	4	3
Feldspar	1	3

Remarks: calcite present

Other Tests:

pH: 7.55
Workability: not plastic, short and gritty
Water of plasticity %: 15.0
% Drying shrinkage: 3.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	4.0	24.3	2.67
1900	Brown red	Hard	5.0	12.9	2.66
2000	Brown red	Very hard	5.0	10.6	2.65
2100	Dk. brown	Steel hard	7.5	8.0	2.52
2200	Dk. brown	Expanded and melting			

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.65	120.8	13.9	No bloating
1900	1.41	87.8	18.3	No bloating
2000	0.98	61.1	21.1	Good expansion
2100	0.94	58.6	23.4	Good expansion
2200	0.61	38.0	28.8	Overfired, melting and sticky

Evaluation: The absorption is higher than most commercial aggregates, but the bloating range and weights are very good. This shale would make a fair quality lightweight aggregate.

Potential Uses: Fair lightweight aggregate; possibly brick.

Remarks: Slight scumming at 1900-2000°F indicating a small amount of calcium sulfate or carbonate. Fired colors are very poor.

SOMERSET COUNTY

Sample Number

59-5-3

Quadrangle: Meyersdale 15'

Location: General Refractories strip mine operations about 3.4 miles south-southeast of Rockwood and on the south side of an improved road about 1.3 miles northwest of Lick Run School.

Geologic Unit: Mercer horizon, Pottsville Group, Pennsylvanian Age

Description: A stockpile of medium-to medium-dark-gray flint clay, which has been mined and shipped from a mine south of Rockwood, is located at the site of the General Refractories Fort Hill Mine. The deposit of flint clay is reported to be from 1 to 3 feet thick.

Sampled Interval: Grab sample from stockpile.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	46.40
Al_2O_3	35.70
Fe_2O_3	.55
FeO	.59
CaO	.09
MgO	.18
K_2O	.99
Na_2O	.35
TiO_2	2.29
L.O.I.	12.85
S	.018
CO_2	.84
comb. H_2O	12.01

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	8	5
Mica	20	8
Kaolinite	63	12
C-V-Mo	5	3
Feldspar	1	2

Other Tests:

pH: 5.5
Workability: not very plastic, slightly gritty, short, hardens on standing
Water of plasticity %: 18.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. buff	Soft, crumbly	5.0	16.9	2.66
1900					
2000	Lt. ivory	Soft, crumbly	5.0	15.6	2.67
2100	Lt. ivory	Fairly hard	5.0	12.7	2.68
2200	Lt. buff	Hard	5.0	12.2	2.71
2300	Lt. buff	Very hard	7.5	10.9	2.73
2400	Lt. gray buff	Steel hard	7.5	11.8	2.74

Bloating Test: Negative

Pyrometric cone equivalent: 34+ **Cone color:** Dark cream

Potential Uses: Super-duty refractory products.

SOMERSET COUNTY

Sample Number

59-6-1

Quadrangle: Meyersdale 15'

Location: Along the north side of the Baltimore and Ohio Railroad tracks, about 2.4 miles northwest of Meyersdale.

Geologic Unit: Friendsville shale, Conemaugh Formation, Pennsylvanian Age

Description: Medium-dark-gray, carbonaceous, thin-bedded shales of the marine Friendsville shale are exposed for a distance of 250 feet along the railroad. Non-marine shales of a light tan color occur stratigraphically above the Friendsville in this exposure. The upper 3 feet of the Friendsville is weathered more than the lower portion and has more iron-staining along fractures.

Attitude of Bedding: Horizontal

Sampled Interval: 12-foot channel sample through the upper portion of the Friendsville shale.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	55.00
Al_2O_3	19.85
Fe_2O_3	7.71
FeO	1.28
CaO	.13
MgO	1.33
K_2O	3.40
Na_2O	.78
TiO_2	.95
L.O.I.	9.39
S	.19
CO_2	3.48
comb. H_2O	4.35
H_2O @ 120°C	1.56

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	38	6
Mica	44	8
Kaolinite	6	5
C-V-Mo	3	3
Feldspar	1	3

Remarks: carbonate? present

Other Tests:

pH: 4.8
Workability: not plastic, short
Water of plasticity %: 18.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Soft, crumbly	2.5	18.4	2.74
1900	Dk. buff brown	Soft, crumbly	6.5	15.0	2.71
2000	Brown	Very hard	7.5	11.3	2.65
2100	Dk. rich brown	Steel hard	11.0	6.2	2.61
2200	Very dk. gray brown	Steel hard	11.0	3.8	2.42
2300	Very dk. gray brown	Steel hard	Expanding and melting		

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.90	118.4	6.3	No bloating
1900	1.59	99.1	8.6	No bloating
2000	1.23	76.6	14.8	Fair expansion
2100	0.96	59.8	18.3	Good expansion
2200	0.77	48.0	16.6	Good expansion, slightly sticky

Evaluation: The bloating range is good and the aggregate expands uniformly. This material would make a good lightweight aggregate.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	None
Particle shape	Angular & Rounded
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	21.6
—1/4 + 1/8	39.8
—1/8 + 16	38.6
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	12.4
—3/8 + 1/4	11.7
—1/4 + 8	21.6
— 8 + 16	20.9
—16 + 35	12.5
—35 + 65	12.8
—65	8.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1910	1960
Optimum	1940	1980
Maximum	1950	2030

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	73
Fired	53
Effect of quenching	NA
Processing characteristics	Fair
Material flow	U
Point of release	9:00
Particle shape	Angular & Rounded
Pore structure	Fine
Expansion	Fair
Uniformity of firing	NU
Color	Yellow to gray

Specific gravity, weight, absorption

Size	*ASG*	*Lb/ Ft.^{3}*	*% Abs.*
—3/4 + 1/2	NA	NA	NA
—1/2 + 1/4	1.23	76.6	4.69
—1/4 + 8 mesh	1.31	81.6	4.61

Screen analysis

Size	*Percent retained*
+3/8	25.0
—3/8 + 1/4	35.8
—1/4 + 8	25.2
— 8 + 16	11.4
—16 + 35	1.4
—35 + 65	.6
—65	.6
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.42
Lb/Ft^3	88
Compression (PSI)	4878
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	3.8

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.48
Lb/Ft^3	89
Compression (PSI)	4991
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	4.8

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.46	Bulk Sp. Gr.	1.48
Lb/Ft^3	91	Lb/Ft^3	92
Compression (PSI)	6203	Compression (PSI)	5478
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	3.8	% Abs.	5.4

Potential Uses: Brick and fair lightweight aggregate; possibly floor tile.

Remarks: Bloating tests (quick-firing) indicated this material would make a good lightweight aggregate, but subsequent rotary kiln tests on a bulk sample indicated it should be classified as a fair lightweight aggregate material.

SOMERSET COUNTY

Sample Number

59-6-2

Quadrangle: Meyersdale 15'

Location: Outcrop along the north side of U. S. Route 219, about 2.2 miles northwest of Meyersdale.

Geologic Unit: Ames horizon, Conemaugh Formation, Pennsylvanian Age

Description: Dark-gray, fossiliferous, carbonaceous shales of the marine Ames shale is exposed for a distance of about 500 feet along the roadway. Siderite nodules occur along bedding planes in a few places. Upon weathering, the shale breaks down into platy, chip-sized fragments. The Ames shale occurs stratigraphically above the Harlem coal.

Sampled Interval: Channel sample taken from 2 to 12 feet stratigraphically above the Harlem coal.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	51.40
Al_2O_3	18.25
Fe_2O_3	5.75
FeO	2.32
CaO	3.45
MgO	1.56
K_2O	3.20
Na_2O	.65
TiO_2	.83
L.O.I.	12.55
S	1.23
CO_2	10.94
H_2O @ 120°C	1.79

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	29	6
Mica	50	8
Kaolinite	6	5
C-V-Mo	3	3
Feldspar	1	3

Remarks: calcite present

Other Tests:

pH: 6.7
Workability: not plastic, short
Water of plasticity %: 17.0
% Drying shrinkage: 3.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff brown	Fairly hard	5.0	18.4	2.71
1900	Dk. buff brown	Very hard	5.0	13.4	2.65
2000	Lt. brown	Steel hard	7.5	10.9	2.61
2100	Brown	Steel hard	7.5	9.5	2.42
2200	Very dk. brown	Steel hard	Expanding and melting		

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1800	1.44	89.7	13.9	No bloating
1900	1.23	76.6	16.7	Slight expansion
2000	1.20	74.8	17.5	Fair bloating
2100	1.04	64.7	17.6	Fair bloating
2200	0.62	38.6	15.7	Overfired, fragile and very sticky

Evaluation: The material does not expand uniformly. It would make a fair lightweight aggregate.

Potential Uses: Brick and fair lightweight aggregate; possibly floor tile.

Remarks: Slightly effervescent indicating calcium carbonate or calcium sulfate, also slight scumming.

SOMERSET COUNTY

Sample Number

59-7-1A

Quadrangle: Meyersdale 15'

Location: General Refractories Fort Hill Mine about 2.8 miles southeast of the town of Fort Hill.

Geologic Unit: Clarion underclay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-gray, soft clay, which is from 5 to 6 feet thick, underlies the Clarion coal. This clay is underlain by a flint clay which measures 67 inches in thickness. The quarry workings are extensive.

Attitude of Bedding: N44E, 5NW

Sampled Interval: Channel sample taken from 0 to 5 feet below the Clarion coal.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	61.20
Al_2O_3	24.40
Fe_2O_3	.55
FeO	.59
CaO	.10
MgO	.25
K_2O	1.75
Na_2O	.33
TiO_2	1.70
L.O.I.	9.06
S	.34
CO_2	1.06
comb. H_2O	8.00

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	41	8
Mica	40	8
Kaolinite	19	10
C-V-Mo	0	2
Feldspar	0	3

Other Tests:

pH: 4.3
Workability: not plastic, short
Water of plasticity %: 17.0
% Drying shrinkage: 2.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. yellowish tan	Soft, crumbly	4.0	17.9	2.65
1900	Lt. yellowish tan	Hard	4.0	16.6	2.66
2000	Lt. yellowish tan	Very hard	4.0	15.4	2.65
2100	Lt. tan	Steel hard	7.0	12.0	2.64
2200	Lt. tan	Steel hard	10.0	7.5	2.58
2300	Lt. tan gray	Steel hard	10.0	4.9	2.54

Bloating Test: Negative

Pyrometric cone equivalent: 27 **Cone color:** Light gray

Potential Uses: Decorative brick, low-duty refractories; possibly chimney flue tile.

SOMERSET COUNTY

Sample Number

59-7-1B

Quadrangle: Meyersdale 15'

Location: General Refractories Fort Hill Mine about 2.8 miles southwest of the town of Fort Hill.

Geologic Unit: Clarion underclay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: Medium-to dark-gray flint clay occurs about 5 to 6 feet below the Clarion coal and is separated from it by a soft clay. The flint clay has well-developed conchoidal fractures, is relatively hard, and breaks into irregular fragments with very sharp edges. The thickness of the flint clay at the sample site is 67 inches but is reported to average three feet in thickness in the quarry.

Attitude of Bedding: N44E, 5NW

Sampled Interval: 67-inch channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	60.30
Al_2O_3	27.00
Fe_2O_3	.35
FeO	.45
CaO	.04
MgO	.04
K_2O	.35
Na_2O	.12
TiO_2	1.56
L.O.I.	9.73
S	.10
CO_2	1.14
comb. H_2O	8.59

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	45	10
Mica	29	10
Kaolinite	25	10
C-V-Mo	0	2
Feldspar	0	2

Remarks: goethite and diaspore present

Other Tests:

pH: 4.6
Workability: not plastic, short
Water of plasticity %: 16.0
% Drying shrinkage: 2.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Very lt. tan	Soft, crumbly	3.5	17.9	2.59
1900	Very lt. tan	Soft, crumbly	4.0	17.8	2.66
2000	Lt. gray	Soft, crumbly	4.0	18.0	2.66
2100	Lt. gray	Soft, crumbly	4.0	17.6	2.65
2200	Lt. gray	Fairly hard	5.0	16.2	2.66
2300	Lt. ivory	Hard	7.5	14.2	2.68

Bloating Test: Negative

Pyrometric-cone equivalent: 29+ **Cone color:** Off white

Potential Uses: Intermediate-duty refractories.

SOMERSET COUNTY

Sample Number

59-11-4

Quadrangle: Grantsville 15'; Grantsville 7½'

Location: Otto Brick and Tile Works quarry about 0.5 mile northeast of the town of Springs.

Geologic Unit: Lake deposit, Quaternary Age

Description: Clay which was probably deposited in a lake that formed behind a natural dam of resistant Grafton sandstone is being quarried at this location. The clay measures up to 16 feet in thickness and consists of a 2-foot upper zone of gray clay that appears to be leached, a 5-foot middle zone of interlayered gray and gray-brown clay, and a lower zone of brown, plastic clay which is about 5 feet thick. A few sandstone fragments, up to several inches in length, are scattered throughout the middle zone.

Sampled Interval: Channel sample taken 0-10 feet vertically below surface of deposit.

Type of Material: clay

Chemical Analysis:

	%
SiO_2	69.20
Al_2O_3	11.40
Fe_2O_3	3.93
FeO	.61
CaO	3.30
MgO	.68
K_2O	1.93
Na_2O	.27
TiO_2	.82
L.O.I.	7.85
S	.018
CO_2*	3.73
comb. H_2O	3.13
H_2O @ 120°C	.97

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	53	6
Mica	24	6
Kaolinite	15	8
C-V-Mo	0	2
Feldspar	0	2

Remarks: carbonate present

Other Tests:

pH: 8.1
Workability: plastic, smooth and very gritty
Water of plasticity %: 21.0
% Drying shrinkage: 2.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	2.5	16.5	2.64
1900	Brown	Soft, crumbly	2.5	15.7	2.65
2000	Brown	Fairly hard	2.5	15.8	2.66
2100	Dk. brown	Very hard	2.5	13.4	2.66
2200	Dk. brown	Steel hard	7.5	4.0	2.39
2300	Melting and Expanding				

Bloating Test: Negative

Potential Uses: Brick, tile, and drain tile.

SOMERSET COUNTY

Sample Number

69-2-1

Quadrangle: Berlin 15'

Location: Quarry located north of the paved road leading from Berlin to Deeters Gap, about 0.6 mile east-northeast of Macdonaldton.

Geologic Unit: Mt. Savage clay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: The clay zone is made up of two parts. The upper part consists of a medium-gray, soft, nodular clay with subconchoidal fracturing. It grades down into a light- to medium-gray, massive clay which becomes silty with depth. Iron-staining is common along fracture surfaces. The thickness of the clay zone is about 9 feet. The quarry workings are extensive; quarry walls are estimated to be about 25 feet high.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 9-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.10
Al_2O_3	28.00
Fe_2O_3	.19
FeO	.44
CaO	.06
MgO	.07
K_2O	.10
Na_2O	.38
TiO_2	1.60
L.O.I.	9.97
S	.21
CO_2	.70
comb. H_2O	8.62
H_2O @ 120°C	.65

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	50	12
Mica	15	10
Kaolinite	25	20
C-V-Mo	3	3
Feldspar	1	3

Remarks: goethite present

Other Tests:

pH: 4.1
Workability: not plastic, short and gritty
Water of plasticity %: 19.0
% Drying shrinkage: 2.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. pink	Soft, crumbly	4.0	17.1	2.59
1900	Lt. pink	Soft, crumbly	5.0	17.4	2.65
2000	Very lt. pink	Soft, crumbly	5.0	17.3	2.64
2100	Lt. gray	Soft, crumbly	5.0	17.5	2.62
2200	Lt. gray ivory	Hard	5.0	16.0	2.64
2300	Lt. ivory	Very hard	5.0	14.4	2.67

Bloating Test: Negative

Pyrometric cone equivalent: 30 **Cone color:** Off white

Potential Uses: Intermediate-duty refractories.

SUSQUEHANNA COUNTY

Sample Number

192-5-1

Quadrangle: Dundaff 15'; Lenoxville 7½'

Location: East side of Interstate Highway Route 81, about 0.3 mile north of the southern border of Susquehanna County.

Geologic Unit: Catskill Formation, Susquehanna Group, Devonian Age

Description: A section of pale-red to gray-red, thin-bedded shales, is exposed in the southern part of this exposure. This section is 32 feet thick. It contains a few beds of green-gray shales and, in the lower part, some sandy shale beds. It is bounded above and below by massive sandstone beds. Upon impact, the thin-bedded shales break into small, hackly fragments that measure from 1 to 2 inches in length. The sandy beds range up to 2 feet in thickness.

Attitude of Bedding: N40E; 11S

Sampled Interval: 32-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	62.55
Al_2O_3	18.20
Fe_2O_3	5.79
FeO	2.28
CaO	.15
MgO	.88
K_2O	4.49
Na_2O	.53
TiO_2	1.01
L.O.I.	4.10
S	.014
CO_2*	.22
comb. H_2O	3.53
H_2O @ 120°C	.34

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	6
Mica	50	8
Kaolinite	5	3
C-V-Mo	1	2
Feldspar	1	2

Other Tests:

pH: 7.5
Workability: slightly plastic, short, fine grit
Water of plasticity %: 19.0
% Drying shrinkage: 4.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown buff	Soft, crumbly	5.0	15.5	2.60
1900	Brown buff	Soft, crumbly	6.0	11.8	2.61
2000	Brown buff	Hard	6.0	11.0	2.62
2100	Dk. brown	Steel hard	9.0	7.8	2.62
2200	Dk. brown	Steel hard	10.0	0.6	2.58
2300	Melting				

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.60	99.7	8.2	No bloating
2000	1.54	95.9	11.2	No bloating
2100	1.42	88.5	5.6	No bloating
2200	1.60	99.7	4.2	No bloating

Evaluation: No bloating.

Potential Uses: Possibly brick and sintered aggregate.

Remarks: Acid treatment shows a small amount of calcareous material.

UNION COUNTY

Sample Number

144-5-1

Quadrangle: Milton 15'

Location: West side of U. S. Highway 15 along the north flank of South White Deer Ridge, about one mile south of Allenwood.

Geologic Unit: Rose Hill Formation, Clinton Group, Silurian Age

Description: Interbedded greenish-gray, thin- to medium-bedded shales and siltstones are exposed for a distance of about 2500 feet along the highway. The section also contains a few thin sandstone beds. The beds measure from less than one inch to 12 inches in thickness. Weathered surfaces of the rock are commonly brown or reddish-brown in color. Fragments of the rock are platy, tabular or irregular in shape.

Attitude of Bedding: N70W; 27N

Sampled Interval: 20-foot channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	60.65
Al_2O_3	19.70
Fe_2O_3	3.21
FeO	4.26
CaO	.20
MgO	1.35
K_2O	3.96
Na_2O	.35
TiO_2	.95
L.O.I.	5.32
S	.045
CO_2*	.82
comb. H_2O	4.50
H_2O @ 120°C	.44

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	33	8
Mica	45	8
Kaolinite	13	8
C-V-Mo	1	3
Feldspar	0	2

Remarks: carbonates present

Other Tests:

pH: 8.2
Workability: fairly plastic, smooth, gritty, hardens on standing
Water of plasticity %: 24.4
% Drying shrinkage: 4.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff	Fairly hard	0.0	14.9	2.60
1900	Dk. buff orange	Very hard	0.0	10.5	2.63
2000	Brown	Very hard	5.5	7.7	2.63
2100	Dk. brown	Steel hard	9.5	2.5	2.58
2200	Very dk. brown	Steel hard	9.5	0.0	2.43
2300	Gray black		Expanded	1.4	2.20

Bloating Test: Slight expansion

Potential Uses: Possibly sintered aggregate.

Remarks: Acid treatment shows a small amount of calcareous material.

WASHINGTON COUNTY

Sample Number

8-5-2

Quadrangle: Claysville 15'; Washington West 7½'

Location: North side of Interstate Highway 70, about 6 miles southwest of the city of Washington and 0.35 mile north of Highland School.

Geologic Unit: Greene Formation, Permian Age

Description: Dark-gray, hard, massive claystone, 8 feet thick, is exposed near the bottom of the roadcut at the sample site and is bounded above and below by limestone. The claystone breaks into tabular-shaped fragments with conchoidal fractures and very sharp edges. It occurs about 100 feet stratigraphically above the top of the Washington Formation.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 8-foot channel sample

Type of Material: claystone

Chemical Analysis:

	%
SiO_2	54.00
Al_2O_3	19.95
Fe_2O_3	.65
FeO	6.92
CaO	3.10
MgO	1.65
K_2O	3.12
Na_2O	.78
TiO_2	.83
L.O.I.	8.98
S	.23
CO_2*	2.85
comb. H_2O	6.13
H_2O @ 120°C	.90

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	6
Mica	39	8
Kaolinite	13	6
C-V-Mo	3	3
Feldspar	1	2

Remarks: carbonates present

Other Tests:

pH: 9.05
Workability: not very plastic, short, gritty and slightly fatty
Water of plasticity %: 19.2
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Med. buff brown	Soft, crumbly	5.0	14.8	2.67
1900	Med. buff brown	Soft, crumbly	5.0	14.4	2.69
2000	Brown red	Hard	9.0	9.8	2.67
2100	Dk. brown	Steel hard	10.0	3.5	2.55
2200	Very dk. brown	Steel hard	10.0	0.2	2.28
2300	Melted				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼"

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.69	105.2	8.5	No bloating
2000	1.35	84.1	12.9	Slight bloating
2100	1.06	66.0	12.4	Good bloating
2200	0.75	46.7	16.2	Excellent bloating
2300	0.78	48.6	9.2	Overbloated and very sticky

Evaluation: This material has a long-firing range. It would probably make an excellent lightweight aggregate by the rotary kiln process.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Poor
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	*Percent retained*
—3/8 + 1/4	49.3
—1/4 + 1/8	31.8
—1/8 + 16	18.9
Total	100.0

Screen analysis

Size	*Percent retained*
+3/8	22.9
—3/8 + 1/4	30.5
—1/4 + 8	19.7
— 8 + 16	11.7
—16 + 35	3.7
—35 + 65	7.2
—65	4.3
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	*Part.*
Minimum	1890	1940
Optimum	1950	2000
Maximum	1970	2050

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	96
Fired	46
Effect of quenching	NA
Processing characteristics	Poor
Material flow	U
Point of release	11:00
Particle shape	Angular, Elongated & Platy
Pore structure	Medium, Fine
Expansion	Poor
Uniformity of firing	NU
Color	Gray to black

Specific gravity, weight, absorption

Size	*ASG*	*Lb/Ft.³*	*% Abs.*
—3/4 + 1/2	1.56	97.2	14.0
—1/2 + 1/4	1.37	85.4	10.7
—1/4 + 8 mesh	1.45	90.3	9.3

Screen analysis

Size	*Percent retained*
+3/8	28.1
—3/8 + 1/4	63.4
—1/4 + 8	6.6
— 8 + 16	.6
—16 + 35	.6
—35 + 65	.6
—65	1.1
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.46
Lb/Ft³	91
Compression (PSI)	4967
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	4.7

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.53
Lb/Ft³	95
Compression (PSI)	3407
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	6.1

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.51	Bulk Sp. Gr.	1.56
Lb/Ft^3	94	Lb/Ft^3	97
Compression (PSI)	6105	Compression (PSI)	4919
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	6.2	% Abs.	6.5

Potential Uses: Brick, fair lightweight aggregate; possibly floor tile.

Remarks: Bloating tests (quick-firing) indicated this material would probably make an excellent lightweight aggregate; however, the results of the rotary kiln tests on a bulk sample indicated it would only make a fair lightweight aggregate material:

WASHINGTON COUNTY

Sample Number

8-6-1

Quadrangle: Claysville 15'; Washington West 7½'

Location: Slope exposure about 0.4 mile west of Reservoir No. 1 near Franklin Farms and about 0.4 mile south of Elwood Park, Pennsylvania.

Geologic Unit: Washington Formation, Permian and Pennsylvanian Age

Description: Medium-light-gray to light-olive-gray, interbedded shales and siltstones, stratigraphically in the lower part of the middle member of the Washington Formation, are exposed on the slope. The section measures 14 stratigraphic feet. A few beds in the lower part of the section contain siderite nodules.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	53.60
Al_2O_3	19.00
Fe_2O_3	3.77
FeO	5.55
CaO	1.25
MgO	1.49
K_2O	3.18
Na_2O	.57
TiO_2	.94
L.O.I.	10.60
S	.26
CO_2*	4.36
comb. H_2O	6.24
H_2O @ 120°C	1.02

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	27	6
Mica	48	8
Kaolinite	14	7
C-V-Mo	2	2
Feldspar	1	2

Remarks: calcite and siderite (?) present

Other Tests:

pH: 9.3
Workability: not very plastic, short, gritty and slightly fatty
Water of plasticity %: 19.0
% Drying shrinkage: 5.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Med. buff brown	Soft, crumbly	5.0	15.3	2.67
1900	Med. buff brown	Soft, crumbly	5.0	14.1	2.69
2000	Buff red	Steel hard	6.0	11.4	2.68
2100	Dk. brown	Steel hard	9.5	5.2	2.53
2200	Very dk. brown	Steel hard	6.5	4.4	2.23
2300	Melting				

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.72	107.2	9.6	No bloating
2000	1.66	103.4	8.4	No bloating
2100	1.38	86.0	5.7	Fair expansion
2200	1.05	65.4	10.2	Overbloated and sticky
2300	0.70	43.6	14.9	Overbloated, melting and very sticky

Evaluation: The composition of this material is not uniform. It has layers of low-fusing material which overbloats and melts. Part of the material expands satisfactorily. It would probably make a fair quality sintered aggregate.

Potential Uses: Brick; possibly floor tile and sintered aggregate.

WASHINGTON COUNTY

Sample Number

18-1-1A

Quadrangle: Amity 15'; Washington East 7½'

Location: Donley Brick Company quarry located on the north side of U. S. Route 40 in the southeast part of Washington, and about one mile northeast of the town of Laboratory.

Geologic Unit: Washington Formation, Permian and Pennsylvanian Age

Description: Fifteen feet of light-to medium-greenish-gray, thin-bedded shales and siltstones occur between the upper limestone member and the Jollytown coal horizon in the Washington Formation. The upper four feet contain about 3 to 5 percent of siderite nodules.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 15-foot channel sample

Type of Material: interbedded shale and siltstone

Chemical Analysis:

	%
SiO_2	60.70
Al_2O_3	20.10
Fe_2O_3	5.29
FeO	137
CaO	.77
MgO	1.06
K_2O	2.82
Na_2O	.62
TiO_2	.99
L.O.I.	6.25
S	.028
CO_2*	.74
comb. H_2O	5.51
H_2O @ 120°C	1.79

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	47	10
Mica	30	8
Kaolinite	4	4
C-V-Mo	5	3
Feldspar	1	3

Remarks: some montmorillonite (Mo) present

Other Tests:

pH: 8.9
Workability: plastic and smooth, slightly short
Water of plasticity %: 20.8
% Drying shrinkage: 7.0
Dry strength: above average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	7.5	21.2	2.61
1900	Buff orange	Fairly hard	8.5	9.8	2.58
2000	Brown	Very hard	10.0	7.2	2.59
2100	Med. brown	Steel hard	11.0	3.3	2.50
2200	Dk. brown	Steel hard	10.0	4.0	2.30
2300	Dk brown	Steel hard	14.5	1.1	2.21

Bloating Test: Negative

Potential Uses: Brick, floor tile, sintered aggregate.

WASHINGTON COUNTY

Sample Number

18-1-1B

Quadrangle: Amity 15'; Washington East 7½'

Location: Donley Brick Company quarry located on the north side of U. S. Route 40, in the southeast part of Washington, and about one mile northeast of the town of Laboratory.

Geologic Unit: Washington Formation, Permian and Pennsylvanian Age

Description: Six and one-half feet of shale and siltstone are exposed below the Jollytown coal horizon in the quarry. The upper foot consists of an orange clay which is underlain by 54 inches of thin-bedded, pale-olive-gray shale and 12 inches of medium-gray, thin-bedded siltstone.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 6½-foot channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	58.20
Al_2O_3	20.70
Fe_2O_3	7.66
FeO	.61
CaO	.67
MgO	1.02
K_2O	2.89
Na_2O	.63
TiO_2	.93
L.O.I.	6.67
S	.028
CO_2*	.67
comb. H_2O	6.00
H_2O @ 120°C	2.31

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	7
Mica	45	8
Kaolinite	0	2
C-V-Mo	5	3
Feldspar	1	3

Other Tests:

pH: 7.5
Workability: plastic, smooth, slightly short
Water of plasticity %: 24.1
% Drying shrinkage: 6.0
Dry strength: above average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff brown	Very hard	10.0	11.6	2.65
1900	Lt. buff brown	Steel hard	10.0	7.0	2.50
2000	Brown	Steel hard	12.5	1.9	2.29
2100	Dk. brown	Steel hard	17.5	0.9	2.26
2200	Very dk. brown	Steel hard	Expanded	0.1	2.23

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.15	133.9	9.0	No bloating
2000	2.22	138.3	4.7	No bloating
2100	1.70	105.9	6.0	Excellent expansion
2200	1.75	109.0	0.0	Good expansion, slightly sticky
2300	1.50	93.5	2.0	Overbloated and very sticky

Evaluation: This sample is a mixture of weathered and unweathered material. The unweathered material has excellent expanding properties but the weathered material does not expand.

Potential Uses: Brick and floor tile; possibly sintered aggregate.

WASHINGTON COUNTY

Sample Number

18-6-3

Quadrangle: Amity 15'; Ellsworth 7½'

Location: Exposure on the south side of State Route 71, about 200 feet east of the western boundary of the Borough of Ellsworth.

Geologic Unit: Uniontown horizon, Monongahela Formation, Pennsylvanian Age

Description: The underclay to the Waynesburg coal is exposed about half way up the south slope along State Route 71. It is orange, yellow and gray in color and contains two thin silty layers and a 4-inch layer of siderite nodules. The underclay is 5 feet thick and is reported to underlie an extensive area.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 9-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.65
Al_2O_3	20.00
Fe_2O_3	5.58
FeO	1.67
CaO	.10
MgO	.96
K_2O	2.93
Na_2O	.66
TiO_2	1.04
L.O.I.	7.37
S	.18
CO_2*	1.92
comb. H_2O	5.45
H_2O @ 120°C	1.63

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	41	8
Kaolinite	0	3
C-V-Mo	8	3
Feldspar	1	3

Remarks: carbonates present

Other Tests:

pH: 4.8
Workability: plastic and smooth, slightly fatty
Water of plasticity %: 23.8
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	5.0	19.2	2.65
1900	Buff orange	Soft, crumbly	5.0	19.1	2.65
2000	Buff orange	Fairly hard	5.0	17.7	2.64
2100	Brown	Steel hard	10.0	9.9	2.62
2200	Dk. brown	Steel hard	10.0	5.3	2.52
2300	Gray black	Steel hard	Expanded	3.8	2.34

Bloating Test: Slight expansion

Potential Uses: Brick and floor tile.

Remarks: Acid treatment shows presence of considerable calcareous material.

WASHINGTON COUNTY

Sample Number

18-6-3

Quadrangle: Amity 15'; Ellsworth 7½'

Location: Exposure on the south side of State Route 71, about 200 feet east of the western boundary of the Borough of Ellsworth.

Geologic Unit: Uniontown horizon, Monongahela Formation, Pennsylvanian Age

Description: The underclay to the Waynesburg coal is exposed about half way up the south slope along State Route 71. It is orange, yellow and gray in color and contains two thin silty layers and a 4-inch layer of siderite nodules. The underclay is 5 feet thick and is reported to underlie an extensive area.

Attitude of Bedding: Essentially horizontal

Sampled Interval: Five-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.65
Al_2O_3	20.00
Fe_2O_3	5.58
FeO	1.67
CaO	.10
MgO	.96
K_2O	2.93
Na_2O	.66
TiO_2	1.04
L.O.I.	7.37
S	.18
CO_2*	1.92
comb. H_2O	5.45
H_2O @ 120°C	1.63

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	8
Mica	41	8
Kaolinite	0	3
C-V-Mo	8	3
Feldspar	1	3

Remarks: carbonates present

Other Tests:

pH: 4.8
Workability: plastic and smooth, slightly fatty
Water of plasticity %: 23.8
% Drying shrinkage: 5.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	5.4	19.2	2.65
1900	Buff orange	Soft, crumbly	5.0	19.1	2.65
2000	Buff orange	Fairly hard	5.0	17.7	2.64
2100	Brown	Steel hard	10.0	9.9	2.62
2200	Dk. brown	Steel hard	15.0	5.3	2.52
2300	Gray black	Steel hard	Exp.	3.8	2.34

Bloating Test: Slight expansion

Potential Uses: Brick and floor tile.

Remarks: Acid treatment shows presence of considerable calcareous material.

WASHINGTON COUNTY

Sample Number

28-4-1

Quadrangle: Brownsville 15'; Monongahela 7½'

Location: An exposure on the northwest side of State Route 71, about 0.4 mile southwest of the Fallowfield Township School.

Geologic Unit: Washington Formation, Permian and Pennsylvanian Age

Description: An exposure of rust-colored clay, 9 feet thick, occurs from 6 to 15 feet below the Waynesburg "A" coal. A sandstone bed, one foot thick, underlies the clay zone.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 9-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	56.90
Al_2O_3	20.90
Fe_2O_3	5.32
FeO	1.22
CaO	1.97
MgO	1.11
K_2O	3.20
Na_2O	.57
TiO_2	.93
L.O.I.	7.85
S	.035
CO_2*	1.41
comb. H_2O	6.44
H_2O @ 120°C	1.27

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	36	6
Mica	44	8
Kaolinite	3	3
C-V-Mo	5	3
Feldspar	1	3

Remarks: carbonates and montmorillonite (Mo) or vermiculite (V) present

Other Tests:

pH: 8.4
Workability: plastic, smooth, gritty
Water of plasticity %: 22.1
% Drying shrinkage: 1.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff orange	Soft, crumbly	5.0	17.1	2.60
1900	Buff orange	Very hard	5.0	13.7	2.61
2000	Brown	Steel hard	9.0	8.8	2.58
2100	Dk. brown	Steel hard	9.5	5.2	2.53
2200	Very dk. brown	Steel hard	9.5	2.6	2.12
2300	Very dk. brown gray	Steel hard	Expanded	6.4	2.27

Bloating Test: Slight expansion

Potential Uses: Brick, tile, possibly sintered aggregate.

Remarks: Acid treatment shows appreciable quantities of calcareous material.

WASHINGTON COUNTY

Sample Number

28-5-2

Quadrangle: Brownsville 15'; California 7½'

Location: Exposure along the north side of Interstate Highway 70 S, about 1.5 miles southwest of Speers and about 1 mile east of Ebenezer Church.

Geologic Unit: Monongahela Formation, Pennsylvanian Age

Description: Carbonaceous, fissile shales, 10 feet thick, are exposed along the highway for a distance of about 2000 feet. Stratigraphically, they occur about 20 feet above the base of the Pittsburgh coal. Siderite bands separate many of the shale beds and make up about 5 percent of the section. The shale grades upward into silty beds.

Attitude of Bedding: Essentially horizontal

Sampled Interval: 10-foot channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	53.60
Al_2O_3	20.25
Fe_2O_3	6.61
FeO	3.19
CaO	.47
MgO	1.11
K_2O	3.02
Na_2O	.31
TiO_2	.97
L.O.I.	10.44
S	.14
CO_2*	7.13
comb. H_2O	3.31
H_2O @ 120°C	.76

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	33	8
Mica	39	8
Kaolinite	15	8
C-V-Mo	3	3
Feldspar	1	2

Remarks: carbonates and montmorillonite (Mo) or vermiculite (V) present

Other Tests:

pH: 9.1
Workability: not plastic, short, mealy and gritty
Water of plasticity %: 14.4
% Drying shrinkage: 0.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Sandy brown	Soft, crumbly	1.0	17.4	2.68
1900	Sandy brown	Soft, crumbly	4.0	15.0	2.72
2000	Brown	Very hard	4.0	10.1	2.68
2100	Dk. brown	Steel hard	6.0	7.6	2.64
2200	Gray black	Steel hard	6.0	3.5	2.58
2300	Gray black	Steel hard	6.0	4.0	2.55

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.26	140.8	3.2	No bloating
2000	1.38	86.0	0.9	Slight bloating and sticky
2100	1.06	66.0	1.0	Fair bloating, very sticky
2200	0.78	48.6	1.0	Overbloated and very sticky

Evaluation: The bloating range for this material is short for rotary kiln processing but it would probably make a high-quality sintered aggregate. Further testing is recommended.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Poor
Particle shape	Platy
Particle thickness	Nonuniform
Uniformity	Weathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	67.0
—1/4 + 1/8	27.9
—1/8 + 16	5.1
Total	100.0

Screen analysis

Size	Percent retained
+3/8	31.8
—3/8 + 1/4	43.7
—1/4 + 8	18.2
— 8 + 16	3.3
—16 + 35	.8
—35+ 65	1.1
—65	1.1
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1900	1950
Optimum	1920	1940
Maximum	1960	2040

Retention time (min.)	15.0
Weight (Lb/Ft^3)	
Unfired	73
Fired	45
Effect of quenching	NA
Processing characteristics	Poor
Material flow	U
Point of release	10:00
Particle shape	Angular & Platy
Pore structure	Fine
Expansion	Fair
Uniformity of firing	NU
Color	Gray to black

Specific gravity, weight, absorption

Size	ASG	Lb/ Ft.^{3}	% Abs.
—3/4 + 1/2	1.34	83.5	6.0
—1/2 + 1/4	1.40	87.2	6.2
—1/4 + 8 mesh	1.51	94.1	6.2

Screen analysis

Size	Percent retained
+3/8	37.4
—3/8 + 1/4	50.5
—1/4 + 8	9.1
— 8 + 16	1.0
—16 + 35	.8
—35 + 65	.6
—65	.6
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.55
Lb/Ft^3	96
Compression (PSI)	4423
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	5.0

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.56
Lb/Ft^3	97
Compression (PSI)	3423
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	5.3

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.53	Bulk Sp. Gr.	1.67
Lb/Ft^3	95	Lb/Ft^3	104
Compression (PSI)	5186	Compression (PSI)	4098
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	5.1	% Abs.	7.0

Potential Uses: Good lightweight aggregate.

Remarks: Bloating tests (quick-firing) indicated the temperature range for bloating was short and further testing was recommended. Subsequent rotary kiln tests on a bulk sample indicated that it would make a good lightweight aggregate.

WAYNE COUNTY

Sample Number

202-8-1

Quadrangle: Honesdale 15'; Waymart 7½'

Location: Exposure located on the northwest side of U. S. Route 106, about 0.4 mile northwest of Waymart.

Geologic Unit: Catskill Formation, Susquehanna Group, Devonian Age

Description: Thin-bedded, pale-red to gray-red shales and siltstones, 38 feet thick, are exposed in a quarry. The beds range from less than one inch up to four inches in thickness and are thickest at the base. The quarry extends for a distance of about 300 feet and is between 20 and 25 feet high.

Attitude of Bedding: N37E; 5NW

Sampled Interval: 34-foot channel sample

Type of Material: shale and siltstone

Chemical Analysis:

	%
SiO_2	62.75
Al_2O_3	18.50
Fe_2O_3	6.14
FeO	1.75
CaO	.24
MgO	1.50
K_2O	3.04
Na_2O	.62
TiO_2	1.00
L.O.I.	4.42
S	.018
CO_2*	.15
comb. H_2O	3.90
H_2O @ 120°C	.35

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	6
Mica	42	8
Kaolinite	5	3
C-V-Mo	4	3
Feldspar	1	3

Remarks: hematite, carbonates and montmorillonite (Mo) or vermiculite (V) present

Other Tests:

pH: 6.4
Workability: not very plastic, short with fine grit
Water of plasticity %: 19.0
% Drying shrinkage: 4.0
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	5.0	15.7	2.63
1900	Brown	Hard	5.0	15.8	2.64
2000	Brown	Very hard	5.5	14.4	2.62
2100	Rich brown	Steel hard	7.0	10.3	2.63
2200	Very dk. brown	Steel hard	10.0	2.6	2.44
2300	Very dk. brown	Steel hard	Expanded	1.2	2.21

Bloating Test: Positive

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair (platy) Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	1.80	112.1	7.9	No bloating
2000	1.54	95.9	8.0	No bloating
2100	1.09	67.9	6.7	Good bloating
2200	0.81	50.5	8.5	Overbloated and melting

Evaluation: The bloating range is rather short but the aggregate is uniformly expanded at 2100°F and the absorption is low. Would make a good lightweight aggregate material.

ROTARY KILN TESTS:

Raw Material

Crushing characteristics	Good
Particle shape	Angular
Particle thickness	Nonuniform
Uniformity	Unweathered

Sizes used in rotary kiln

Size	Percent retained
—3/8 + 1/4	61.0
—1/4 + 1/8	24.9
—1/8 + 16	14.1
Total	100.0

Screen analysis

Size	Percent retained
+3/8	23.9
—3/8 + 1/4	36.0
—1/4 + 8	14.7
— 8 + 16	8.4
—16 + 35	5.8
—35 + 65	6.6
—65	4.6
Total	100.0

Fired Material

Kiln wall & particle temp. °F

	K.W.	Part.
Minimum	1950	2000
Optimum	1965	1995
Maximum	2050	2130

Retention time (min.)	15.0
Weight (Lb/Ft³)	
Unfired	107
Fired	56
Effect of quenching	NA
Processing characteristics	Good
Material flow	U
Point of release	10:00
Particle shape	Angular, Rounded & Elongated
Pore structure	Fine
Expansion	Good
Uniformity of firing	NU
Color	Lt. br. to gray

Specific gravity, weight, absorption

Size	ASG	Lb/Ft.³	% Abs.
—3/4 + 1/2	1.30	81.0	9.1
—1/2 + 1/4	1.34	83.5	8.5
—1/4 + 8 mesh	1.49	92.8	7.0

Screen analysis

Size	Percent retained
+3/8	10.0
—3/8 + 1/4	67.1
—1/4 + 8	19.7
— 8 + 16	2.5
—16 + 35	.3
—35 + 65	.2
—65	.2
Total	100.0

Concrete tests:

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.56
Lb/Ft³	95
Compression (PSI)	5902
Color (colorimeter)	NA
Cure	Autoclave
% Abs.	6.1

Bags Cement/Yd.	5
Bulk Sp. Gr.	1.52
Lb/Ft³	95
Compression (PSI)	5626
Color (colorimeter)	NA
Cure	28 Day Steam
% Abs.	7.1

ROTARY KILN TESTS: Concrete Tests (continued):

Bags Cement/Yd.	7	Bags Cement/Yd.	7
Bulk Sp. Gr.	1.52	Bulk Sp. Gr.	1.52
Lb/Ft^3	95	Lb/Ft^3	95
Compression (PSI)	6325	Compression (PSI)	5772
Color (colorimeter)	NA	Color (colorimeter)	NA
Cure	Autoclave	Cure	28 Day Steam
% Abs.	5.9	% Abs.	6.3

Potential Uses: Brick and floor tile, good lightweight aggregate.

WESTMORELAND COUNTY

Sample Number

47-8-1A

Quadrangle: Latrobe 15'

Location: Union Mining Company property in Kingston, about 3 miles southeast of Latrobe.

Geologic Unit: Mercer Formation, Pottsville Group, Pennsylvanian Age

Description: A medium-gray, soft clay, 24 inches thick, occurs 4 inches below the Mercer coal. It is separated from the coal by a bony, carbonaceous shale. The clay is about 30 feet below the surface at the east end of the quarry where the sample was taken.

Attitude of Bedding: N40E; 7NW

Sampled Interval: 24-inch channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	59.00
Al_2O_3	26.91
Fe_2O_3	.98
FeO	.96
CaO	.08
MgO	.50
K_2O	1.56
Na_2O	.42
TiO_2	1.76
L.O.I.	7.75
S	.051
CO_2	1.06
comb. H_2O	6.02
H_2O @ 120°C	.67

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	40	10
Mica	40	10
Kaolinite	12	8
C-V-Mo	1	2
Feldspar	0	2

Other Tests:

pH: 4.5
Workability: fairly plastic and smooth, slightly gritty
Water of plasticity %: 15.0
% Drying shrinkage: 1.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff yellow	Soft, crumbly	4.0	18.5	2.58
1900	Buff yellow	Soft, crumbly	4.0	16.8	2.59
2000	Buff yellow	Very hard	4.0	14.5	2.58
2100	Buff brown	Steel hard	4.0	12.5	2.56
2200	Lt. brown buff	Steel hard	6.0	9.6	2.56
2300	Lt. gray brown	Steel hard	6.5	6.2	2.57

Bloating Test: Negative

Pyrometric cone equivalent: 26-27

Potential Uses: Chimney flue tile; other possible uses are decorative brick, drain tile and low-duty refractories.

Remarks: Low drying and firing shrinkage and fired colors suggest buff brick and tile. It would probably be necessary to use organic clay additives to improve the plasticity.

WESTMORELAND COUNTY

Sample Number

47-8-1B

Quadrangle: Latrobe 15'

Location: Union Mining Company property in Kingston, about 3 miles southeast of Latrobe.

Geologic Unit: Mercer Formation, Pottsville Group, Pennsylvanian Age

Description: Medium-gray to medium-dark-gray, thin-bedded shale, 91 inches thick, is exposed in a quarry wall that extends for a distance of about 400 feet. The shale occurs 5 feet below the Mercer coal and is bounded above and below by siltstone beds.

Attitude of Bedding: N40E; 7NW

Sampled Interval: 91-inch channel sample

Type of Material: shale

Chemical Analysis:

	%
SiO_2	60.40
Al_2O_3	24.60
Fe_2O_3	1.55
FeO	1.00
CaO	.07
MgO	.63
K_2O	2.80
Na_2O	.37
TiO_2	1.23
L.O.I.	7.32
S	.024
CO_2	.99
comb. H_2O	5.68
H_2O @ 120°C	.65

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	6
Mica	40	8
Kaolinite	16	8
C-V-Mo	1	2
Feldspar	0	2

Other Tests:

pH: 4.9
Workability: not very plastic, short working
Water of plasticity %: 15.0
% Drying shrinkage: 1.5
Dry strength: low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Buff yellow	Soft, crumbly	2.5	16.5	2.73
1900	Buff yellow	Soft, crumbly	2.5	15.9	2.63
2000	Buff yellow	Hard	5.0	12.6	2.62
2100	Buff brown	Steel hard	5.0	10.7	2.58
2200	Brown gray	Hard	5.0	7.7	2.52
2300	Melting and expanding				

Bloating Test: Negative

Potential Uses: Chimney flue tile; possibly decorative brick and drain tile.

WESTMORELAND COUNTY

Sample Number

48-2-1

Quadrangle: Donegal 15'

Location: Exposure on the north side of State Route 180, about 1.5 miles southeast of Lycippus.

Geologic Unit: Brookville clay, Clarion Formation, Allegheny Group, Pennsylvanian Age

Description: The Brookville clay, which overlies the Homewood sandstone, is exposed at the surface. It is reported to be from 4 to 5 feet thick and widespread on Chestnut Ridge.

Attitude of Bedding: Dips gently to the northwest

Sampled Interval: Grab sample from surface exposure

Type of Material: clay

Chemical Analysis:

	%
SiO_2	63.80
Al_2O_3	23.10
Fe_2O_3	.85
FeO	.52
CaO	.03
MgO	.57
K_2O	3.05
Na_2O	.32
TiO_2	1.10
L.O.I.	6.60
S	.010
CO_2	.48
comb. H_2O	5.09
H_2O @ 120°	1.03

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	43	7
Mica	36	8
Kaolinite	11	7
C-V-Mo	1	2
Feldspar	1	2

Other Tests:

pH: 4.6
Workability: plastic and smooth
Water of plasticity %: 26.0
% Drying shrinkage: 0.5
Dry strength: average

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Cream	Soft, crumbly	2.5	22.0	2.57
1900	Cream	Soft, crumbly	2.5	21.2	2.59
2000	Cream	Hard	7.0	17.1	2.59
2100	Lt. cream tan	Steel hard	7.5	13.1	2.57
2200	Lt. tan	Steel hard	10.0	6.5	2.49
2300	Tan gray	Steel hard	10.0	3.2	2.42

Bloating Test: Negative

Pyrometric cone equivalent: 20 **Cone color:** Off white

Potential Uses: Decorative brick and tile, chimney flue tile, pottery, artware, low-duty refractories.

Remarks: Excellent properties for brick and tile; color range very good.

YORK COUNTY

Sample Number

148-8-1

Quadrangle: New Cumberland 15'

Location: Glen Gery Shale Brick Corporation quarry about 0.9 mile northeast of Dover.

Geologic Unit: New Oxford Formation, Triassic Age

Description: Reddish-brown, thin-bedded shales of the New Oxford Formation are exposed in a quarry. The shale is weathered and soft to a depth of 8 feet, below which it is unweathered. The height of the quarry wall is about 15 feet. A soil overburden, about 2 feet thick, is present at the surface.

Attitude of Bedding: NE-SW; 15-25NW

Sampled Interval: Channel sample taken from 2 to 12 feet below the surface.

Type of Material: shale

Chemical Analysis:

	%
SiO_2	53.31
Al_2O_3	19.05
Fe_2O_3	8.37
FeO	1.12
CaO	1.80
MgO	2.65
K_2O	3.65
Na_2O	1.45
TiO_2	.92
L.O.I.	7.64
S	.008
CO_2	1.06
comb. H_2O	5.07
H_2O @ 120°C	1.51

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	34	6
Mica	36	8
Kaolinite	3	2
C-V-Mo	5	3
Feldspar	3	2

Remarks: carbonates and montmorillonite (Mo) or vermiculite (V) present

Other Tests:

pH: 7.7
Workability: not plastic, short and gritty
Water of plasticity %: 16.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Lt. brown	Fairly hard	3.0	13.6	2.52
1900	Brown	Very hard	5.0	9.1	2.50
2000	Brown	Steel hard	7.5	6.7	2.44
2100	Dk. brown	Steel hard	8.0	5.8	2.40
2200	Dk. brown	Steel hard	8.0	1.8	2.22
2300	Melted				

Bloating Test: Slight

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft³	% Absorb.	Remarks
1900	2.20	137.0	3.4	No bloating
2000	1.83	114.0	3.5	No bloating
2100	1.74	108.4	2.5	Slight expansion, sticky
2200	1.28	79.7	2.9	Slight expansion, very sticky

Evaluation: This material would probably make good aggregate by the sintering process.

Potential Uses: Brick and tile; possibly sintered aggregate.

YORK COUNTY

Sample Number

149-11-1

Quadrangle: Westminster 15'; Lineboro 7½'

Location: General Mining Associates quarry about 0.1 mile south of Hokes.

Geologic Unit: Wissahickon Schist, Lower Paleozoic Age

Description: Medium-light-gray to medium-gray graphitic clay is exposed in a quarry. It is probably a weathered product of the Wissahickon Schist, near or at its contact with the Wakefield Marble. The thickness of the graphitic clay was not determined but it is at least 5½ feet. It is overlain by an orange sandy clay which in turn is overlain by a gray plastic clay.

Sampled Interval: Grab sample

Type of Material: graphitic clay

Chemical Analysis:

	%
SiO_2	56.50
Al_2O_3	28.85
Fe_2O_3	.83
FeO	.53
CaO	.02
MgO	.62
K_2O	4.52
Na_2O	.26
TiO_2	1.07
L.O.I.	6.76
S	.019
CO_2*	1.49
comb. H_2O	5.27
H_2O @ 120°C	.07

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	23	7
Mica	27	6
Kaolinite	40	12
C-V-Mo	1	2
Feldspar	0	2

Remarks: carbonates present

Other Tests:

pH: 5.5
Workability: fairly plastic, and smooth, slightly gritty
Water of plasticity %: 26.6
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1900	Briquettes were too crumbly to determine properties.				
2000	Lt. gray	Soft, crumbly	0.5	26.3	2.60
2100	Lt. gray tan	Soft, crumbly	5.0	20.5	2.57
2200	Lt. gray tan	Steel hard	5.5	15.1	2.56
2300	Lt. gray tan	Steel hard	9.0	11.6	2.57

Bloating Test: Negative

Pyrometric cone equivalent: 19-23 **Cone color:** Dark tan

Potential Uses: Low-duty refractory products (ladle brick); possibly chimney flue tile; also used as a paint filler.

YORK COUNTY

Sample Number

158-9-1

Quadrangle: Middletown 15'

Location: An exposure in an old pit about 0.3 mile southwest of the crossroads in Highmount. The pit is located on the west side of the paved road trending southwest from Accomac and Highmount to the Lincoln Highway.

Geologic Unit: Chickies Formation, Cambrian Age

Description: A white, sandy, residual clay, probably formed by the decomposition of sericitic schists within the Chickies Formation, is exposed in a pit. The clay was formerly quarried and mixed with other materials for use as a molding sand. The slopes of the pit are now overgrown with vegetation.

Attitude of Bedding: Beds not exposed

Sampled Interval: Grab sample taken in bottom of pit

Type of Material: clay

Chemical Analysis:

	%
SiO_2	70.70
Al_2O_3	17.15
Fe_2O_3	1.42
FeO	1.00
CaO	.02
MgO	.79
K_2O	3.82
Na_2O	.18
TiO_2	1.10
L.O.I.	3.77
S	.012
CO_2	.33
comb. H_2O	3.44

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	49	6
Mica	32	8
Kaolinite	18	10
C-V-Mo	0	2
Feldspar	0	2

Other Tests:

pH: 5.9
Workability: not plastic, short and gritty
Water of plasticity %: 26.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	*Color*	*Hardness*	*% Shk.*	*% Absorb.*	*Approx. Sp. Gr.*
1800	Lt. buff	Soft, crumbly	1.0	27.5	2.62
1900	Lt. buff	Soft, crumbly	2.5	27.1	2.63
2000	Lt. buff	Soft, crumbly	4.0	22.2	2.59
2100	Tan	Fairly hard	6.5	19.9	2.61
2200	Tan gray	Hard	7.0	14.0	2.57
2300	Gray tan	Very hard	9.0	11.1	2.52

Bloating Test: Negative

Potential Uses: None, unless mixed with a more plastic clay.

YORK COUNTY

Sample Number

159-1-1

Quadrangle: York 15'; York 7½'

Location: Quarry located south-southeast of the Glen-Gery Shale Brick Corporation plant, about 1.4 miles east-southeast of the center of the city of York.

Geologic Unit: Conestoga Formation, Ordovician Age

Description: Yellow-orange to yellow-brown residual clay, about 10 feet thick, is exposed in the quarry. The clay formed from the weathering of the underlying Conestoga limestone. A soil overburden, from one to two feet thick, is present at the surface.

Attitude of Bedding: None

Sampled Interval: 8-foot channel (northeast end of quarry)

Type of Material: clay

Chemical Analysis:

	%
SiO_2	60.50
Al_2O_3	18.70
Fe_2O_3	6.95
FeO	.32
CaO	.06
MgO	1.54
K_2O	3.95
Na_2O	1.88
TiO_2	.96
L.O.I.	5.08
S	.016
CO_2	.48
comb. H_2O	4.16
H_2O @ 120°C	.48

Mineralogy: X-ray:

	%	*Accuracy* (±)
Quartz	34	6
Mica	50	10
Kaolinite	0	2
C-V-Mo	2	2
Feldspar	2	2

Remarks: calcite present

Other Tests:

pH: 4.8
Workability: fairly plastic, slightly short, fine grit
Water of plasticity %: 31.0
% Drying shrinkage: 4.0
Dry strength: average

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Dk. buff orange	Soft, crumbly	5.0	23.5	2.35
1900	Dk. buff orange	Soft, crumbly	6.0	17.6	2.36
2000	Lt. brown	Fairly hard	9.0	13.9	2.36
2100	Brown	Very hard	9.5	11.6	2.35
2200	Dk. brown	Very hard	13.0	5.3	2.35
2300	Dk. brown	Steel hard	15.0	0.6	2.22

Bloating Test: Negative

Potential Uses: Brick.

YORK COUNTY

Sample Number

159-1-2

Quadrangle: York 15'; York 7½'

Location: Glen-Gery Shale Brick Corporation quarry about 3.6 miles southeast of the center of the city of York and about 0.8 mile northwest of Ore Valley.

Geologic Unit: Harpers Formation, Cambrian Age

Description: Yellow and reddish-brown clay is exposed in a quarry which is about 15 feet deep. Weathered fragments of phyllite occur within the clay, especially in the lower part. A soil overburden, about 2 feet thick, occurs at the surface.

Attitude of Bedding: None

Sampled Interval: 10-foot channel sample

Type of Material: clay and phyllite

Chemical Analysis:

	%
SiO_2	64.40
Al_2O_3	18.65
Fe_2O_3	4.45
FeO	1.00
CaO	.04
MgO	.67
K_2O	4.60
Na_2O	.22
TiO_2	.98
L.O.I.	4.94
S	.008
CO_2	.15
comb. H_2O	4.79

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	49	6
Mica	34	8
Kaolinite	9	5
C-V-Mo	2	3
Feldspar	1	4

Remarks: carbonates, chlorite (C) and vermiculite (V) present

Other Tests:

pH: 4.4
Workability: not plastic, short and gritty
Water of plasticity %: 28.0
% Drying shrinkage: 1.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800		Specimen too crumbly for properties			
1900					
2000	Buff yellow	Soft, crumbly	3.5	25.3	2.26
2100	Buff yellow	Soft, crumbly	4.0	24.1	2.26
2200	Buff yellow	Soft, crumbly	6.0	20.8	2.26
2300	Brownish gray	Hard	9.0	13.7	2.31

Bloating Test: Negative

Potential Uses: None if used alone but it might be used for brick if blended with the proper clay.

YORK COUNTY

Sample Number

159-1-3

Quadrangle: York 15'; York 7½'

Location: Quarry located about 2.5 miles east of York and about 0.3 mile southeast of the place where Mill Creek crosses under Plank Road.

Geologic Unit: Chickies Formation, Cambrian Age

Description: Reddish-orange and yellow-orange clay overlies dark-gray slate in the Chickies Formation. Minor amounts of quartz-vein material occur scattered throughout the clay. The thickness of the clay is about 9 feet in the east face of the quarry. Two feet of overburden overlies the clay.

Sampled Interval: 9-foot channel sample

Type of Material: clay

Chemical Analysis:

	%
SiO_2	65.80
Al_2O_3	16.90
Fe_2O_3	5.50
FeO	.92
CaO	.05
MgO	.57
K_2O	2.64
Na_2O	.28
TiO_2	1.26
L.O.I.	6.04
S	.010
CO_2	.33
comb. H_2O	5.71

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	6
Mica	44	8
Kaolinite	1	2
C-V-Mo	6	4
Feldspar	0	3

Remarks: vermiculite (V) present

Other Tests:

pH: 4.9
Workability: good, no defects
Water of plasticity %: 23.0
% Drying shrinkage: 1.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Orange buff	Soft, crumbly	1.0	20.3	2.58
1900	Orange buff	Soft, crumbly	1.0	19.6	2.59
2000	Orange buff	Soft, crumbly	1.0	18.2	2.55
2100	Dk. orange brown	Soft, crumbly	5.0	18.5	2.54
2200	Brown	Hard	7.5	12.5	2.50
2300	Dk. brown	Very hard	7.5	9.5	2.47

Bloating Test: Negative

Potential Uses: None

Remarks: This material does not vitrify within commercial firing temperatures for brick. The fired colors would be satisfactory if mixed with a lower-firing clay or shale.

YORK COUNTY

Sample Number

159-1-4

Quadrangle: York 15'; York 7½'

Location: Quarry located about 2.5 miles east of York and about 0.3 mile southeast of the place where Mill Creek crosses under Plank Road.

Geologic Unit: Chickies Formation, Cambrian Age

Description: Dark-gray Chickies slate is exposed in a quarry. The slate is overlain by a residual clay which measures up to 9 feet in thickness. Quartz veins which are up to one inch thick occur within some of the cleavage planes in the slate. The quarry is about 35 feet high in places.

Attitude of Cleavage: N54E; 64SE

Sampled Interval: Channel sample from 13 to 22 feet below the surface in the east face of the quarry

Type of Material: weathered slate

Chemical Analysis:

	%
SiO_2	49.50
Al_2O_3	25.30
Fe_2O_3	9.50
FeO	.54
CaO	.03
MgO	.43
K_2O	4.03
Na_2O	2.10
TiO_2	1.36
L.O.I.	7.20
S	.014
CO_2	.77
comb. H_2O	6.43

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	17	8
Mica	44	8
Kaolinite	11	7
C-V-Mo	3	2
Feldspar	12	5

Remarks: chlorite (C) or vermiculite (V) present

Other Tests:

pH: 4.5
Workability: not plastic, short and gritty
Water of plasticity %: 27.0
% Drying shrinkage: 0.0
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Orange buff	Soft, crumbly	0.0	24.3	2.57
1900	Orange buff	Soft, crumbly	0.0	23.7	2.57
2000	Orange buff	Soft, crumbly	1.0	20.9	2.53
2100	Dk. orange brown	Fairly hard	4.0	15.6	2.47
2200	Brown	Hard	6.0	9.6	2.42
2300	Dk. brown	Very hard	9.0	6.9	2.45

Bloating Test: Negative

Bloating Tests (Quick-Firing):

Crushing characteristics: Fair Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density Lb/Ft³	% Absorb.	Remarks
1800	See below		

Evaluation: An examination of the fired particles indicates that the unweathered material may expand satisfactorily for aggregate.

Potential Uses: None

Remarks: This material does not vitrify within commercial firing temperatures for brick.

YORK COUNTY

Sample Number

169-12-2

Quadrangle: Bel Air 15'; Delta 7½'

Location: Quarry owned by Funkhouser Mills, Division of the Ruberoid Company, located about 1 mile northeast of Delta.

Geologic Unit: Peach Bottom Slate, Lower Paleozoic Age

Description: Blue-black slate which is almost a schist is exposed in the quarry. The slate possesses a well-developed cleavage and contains some quartz veins. Weathered fracture surfaces are commonly stained red brown.

Attitude of Cleavage: N50E; 80-89SE

Sampled Interval: Grab sample from broken rock at working face on the lower level of the quarry

Type of Material: slate

Chemical Analysis:

	%
SiO_2	55.20
Al_2O_3	19.75
Fe_2O_3	5.20
FeO	6.69
CaO	.25
MgO	.99
K_2O	3.42
Na_2O	.49
TiO_2	1.08
L.O.I.	6.92
S	.058
CO_2	5.28
comb. H_2O	1.48
H_2O @ 120°C	.10

Mineralogy: X-ray:

	%	Accuracy (±)
Quartz	42	6
Mica	34	8
Kaolinite	0	3
C-V-Mo	10	6
Feldspar	1	3

Remarks: C-V-Mo is all chlorite; some dolomite present

Other Tests:

pH: 9.0
Workability: not plastic, short and mealy
Water of plasticity %: 19.0
% Drying shrinkage: 0.5
Dry strength: very low

Slow-Firing Tests:

Temp. °F.	Color	Hardness	% Shk.	% Absorb.	Approx. Sp. Gr.
1800	Brown	Soft, crumbly	1.0	25.8	2.76
1900	Brown	Soft, crumbly	2.5	23.1	2.77
2000	Brown	Soft, crumbly	2.5	24.5	2.76
2100	Brown	Soft, crumbly	5.5	17.6	2.76
2200	Dk. brown	Very hard	6.0	11.4	2.50
2300	Dk. brown	Steel hard	Expanded	13.2	2.09

Bloating Test: Slight expansion

Bloating Tests (Quick-Firing):

Crushing characteristics: Good Particle size: —½ + ¼″

Drying characteristics: Good Retention time: 15 Min.

Temp. °F	Bulk Density	Lb/Ft^3	% Absorb.	Remarks
1900	2.24	139.6	4.7	No bloating
2000	1.97	122.7	7.2	No bloating
2100	1.37	85.4	13.8	Slight bloating
2200	1.11	69.2	14.2	Fair bloating

Evaluation: Possibly sintered aggregate.

Potential Uses: Possibly sintered aggregate.

CHEMICAL ANALYSES

The chemical analyses for 150 shale and clay samples are presented in Table 8. The order of presentation is the same as that of the preceding Individual Sample Data section, by county and sample number. The symbols used are explained in the introduction to the Individual Sample Data section. This table provides an easy comparison of the major chemical constituents, such as silica and alumina, in the shale and clay samples of this report. In addition, minor constituents, such as CO_2, iron oxide, and sulfide, which may be deleterious in the manufacture of certain fired products, may be easily compared. Correlation of these analyses with potential use and with rock type are presented in the succeeding section, Evaluation of Analytical Data.

Table 8—*Chemical analyses of shale and clay samples.*

County	*Sample Number*	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	TiO_2	*L.O.I.*	*S*	CO_2	*comb.* H_2O	H_2O @ 120°C
Adams	129-2-1	67.50	19.00	2.64	.46	.04	.18	3.75	.26	.30	5.85	.008	.18	5.67	
	129-7-2	71.00	15.30	2.72	.64	.16	1.58	4.85	.70	.35	2.65	.002	.18	2.33	.14
	139-4-1	53.50	16.50	4.04	3.38	3.32	2.65	4.70	2.90	.68	8.24	.04	3.89	4.35	
	139-6-3	66.70	15.70	6.45	.77	.33	.98	2.40	1.30	1.06	4.24	.004	.11	4.13	
	139-6-4	62.30	18.45	6.88	.92	.47	1.32	2.40	1.75	1.02	4.41	.006	.18	4.23	
	139-9-2	55.80	22.02	7.48	.36	.13	.87	5.00	.34	.97	7.00	.016	.48	5.43	1.09
Allegheny	16-9-2	59.60	19.05	3.51	4.26	.20	1.45	2.99	.89	.94	7.08	.56	3.17*	3.91	.80
	16-9-3	53.20	17.20	2.68	3.65	5.30	2.19	3.21	.45	.77	11.34	.045	4.68*	6.66	1.34
	17-2-1	58.80	21.00	7.23	.99	.48	1.11	2.48	.42	1.00	6.45	.024	.29*	6.16	1.78
	26-4-1	57.40	18.60	5.41	1.06	3.93	1.16	2.49	.22	.86	8.86	.024	2.71*	6.15	2.89
Armstrong	35-9-1	70.30	17.50	1.17	.91	.09	.37	1.27	.39	1.50	6.45	.20	.53*	5.06	.66
Bedford	78-9-1	41.30	9.70	1.40	1.98	17.30	3.26	3.53	.20	.43	20.84	.08	18.15*	2.04	.57
	78-9-2	59.90	19.05	6.01	1.04	.33	.85	3.95	.95	.97	6.92	.20	3.63	2.81	.48
	88-8-1A	66.80	15.50	2.56	3.60	.75	.64	3.15	1.45	.98	4.56	.31	2.05	2.35	.16
	88-8-1B	63.62	17.00	2.30	4.48	.39	1.33	3.80	1.26	.98	4.82	.31	1.68	2.84	.30
	88-8-1C	68.32	14.20	3.98	2.40	.57	1.08	3.00	.90	.96	4.53	.06	.88	3.61	.04
Berks	167-2-4	61.60	16.40	6.83	.80	.21	1.94	5.05	1.58	.83	4.75	.012	.48	3.92	.35
	177-2-1	68.00	12.80	4.41	2.38	.25	2.38	2.70	.98	.65	5.38	.020	.59	4.79	
	177-6-2	58.70	19.70	6.64	2.76	.11	1.22	3.57	1.15	.95	5.12	.006	.66	4.46	
	186-8-2	70.80	12.20	3.26	3.99	.23	1.22	2.06	1.76	.76	3.64	.016	.40	3.24	
	186-9-1	65.00	15.00	4.80	2.52	.24	2.03	3.25	1.10	.77	5.21	.018	1.14	3.71	.36
	187-1-2	60.90	17.50	5.66	2.44	.14	1.46	3.60	.90	1.01	6.33	.01	.66	4.95	.72
	187-4-3	64.90	15.55	7.17	.32	.16	.92	3.50	.50	.84	6.10	.016	1.43	3.71	.96
	187-8-1	64.20	15.90	6.21	.24	.26	1.27	3.15	1.25	.94	6.55	.012	.18	4.76	1.61
Blair	87-6-1	66.60	22.85	.13	.61	.04	.26	.70	.07	1.03	7.68	.032	.29*	7.23	.13
Bucks	207-2-1	56.40	19.50	7.75	1.04	.44	1.92	3.70	3.15	.88	5.20	.014	.26	4.07	.87
Butler	15-2-1	56.65	19.00	2.91	6.08	.48	1.49	3.01	.27	.90	9.16	.40	4.60*	4.56	.34
	15-2-1A	57.10	25.65	2.49	.99	.19	.78	3.06	.31	1.14	8.26	.81	1.25*	7.01	1.15

	25-5-1	56.80	18.80	4.23	4.86	.43	1.22	3.12	.49	.96	9.04	.16	5.43*	3.61	.65
	25-5-2	55.80	22.50	3.96	2.58	1.35	.70	2.59	.28	1.23	8.98	.29	2.00*	6.98	1.46
	25-5-3A	52.50	17.30	4.29	6.92	.53	1.25	2.92	.34	.92	12.98	.42	11.57*	1.41	.58
Carbon	195-2-3	64.50	17.20	4.20	3.95	.17	1.23	3.71	.32	.99	3.72	.014	.15*	3.53	.03
	195-5-2	61.00	18.15	4.08	3.34	.90	1.19	4.03	.62	.91	5.77	.058	1.94*	3.47	.30
	195-7-1	58.00	17.85	3.59	3.42	1.04	1.17	3.85	.56	.86	9.64	.79	5.60*	2.89	.36
Clarion	44-2-1	58.15	27.70	.77	.46	.05	.15	.52	.26	1.40	10.49	.096	.88*	8.72	.79
	44-4-2A	67.40	19.10	1.43	.68	.07	.50	3.03	.38	1.15	6.25	.35	.53*	4.72	.65
	44-4-2B	52.60	20.50	2.95	5.32	.67	1.33	3.31	.66	.97	11.65	.74	7.10*	3.09	.72
	44-4-2C	51.35	19.35	6.40	2.89	.35	1.26	3.34	.68	1.00	13.36	1.41	8.20*	2.94	.81
	44-4-3	55.00	21.00	3.25	3.50	.48	1.20	2.78	.56	1.00	11.17	.89	7.76*	1.65	.87
	44-8-4	53.50	20.10	2.56	6.69	.41	1.17	2.81	.68	.95	11.08	.18	7.61*	2.45	.84
Clearfield	85-2-3	57.00	25.90	1.42	1.64	.13	.47	2.95	.60	1.50	8.32	.41	2.00	6.07	.25
	85-3-4	54.90	22.35	3.50	2.40	.20	1.03	4.05	.50	.99	10.02	.46	9.09	.35	.58
	85-3-5	55.15	28.70	1.06	.80	.15	.46	2.20	.40	1.67	9.36	.07	1.57	7.16	.63
	85-5-2	61.50	19.80	5.82	.84	.04	.65	3.46	.44	.96	6.45	.038	1.46	4.99	
	85-5-6	40.70	40.57	.53	.72	.16	.19	1.35	.60	2.57	12.59	.03	1.14	11.15	.30
	85-6-1	57.45	27.00	.97	.62	.27	.31	2.59	.26	1.45	9.04	.16	.90*	7.21	.77
	95-4-1	59.80	22.60	2.35	.64	.80	.68	3.40	.40	1.21	8.05	.07	2.13	5.85	.32
Cumberland	127-9-1	65.00	14.40	4.92	2.46	.26	1.67	3.23	1.50	.85	5.64	.022	.99	4.65	
	128-2-1	62.30	15.50	3.70	3.36	.98	2.01	3.92	1.30	.82	6.03	.33	.26	5.45	.32
	138-1-1	63.50	14.90	4.53	2.72	.42	1.91	3.98	1.44	.86	5.74	.032	1.10	3.84	.80
	138-7-2	67.90	19.35	1.90	.40	.10	.77	1.90	.11	.97	6.56	.01	.18	6.25	.13
	138-7-2A	68.50	19.30	1.70	.60	.25	.68	1.59	.08	1.00	6.27	.032	.18*	6.01	.05
Dauphin	146-7-1	64.00	17.00	6.48	1.23	.12	1.21	3.98	.60	.98	4.33	.006	.18	4.25	
	148-3-1	68.40	14.00	6.55	.77	.07	.98	3.22	.18	.74	5.06	.012	.26	4.80	
Erie	1-5-1	59.30	17.00	2.57	3.48	2.45	1.71	4.00	.75	.86	7.80	.66	4.47	2.71	.62
Fayette	49-4-1A	45.20	34.20	1.85	1.00	.13	.47	1.97	.42	1.55	13.18	.62	1.98	11.20	
	49-4-1B	45.50	36.40	.60	.40	.06	.09	.11	.23	1.80	14.78	.43	2.02	12.54	.30
Franklin	108-6-1	No chemical analysis													
Fulton	98-9-1	71.90	13.05	4.84	.91	.20	.82	3.10	.90	.89	3.34	.019	.31*	2.57	.44

* CO_2 recalculated from CO_3=.

Table 8—*Chemical analyses of shale and clay samples (continued).*

County	Sample Number	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	TiO_2	L.O.I.	S	CO_2	comb H_2O	H_2O @ 120°C
Huntingdon	96-9-1	91.05	5.00	.21	.76	.05	.15	.91	.08	.30	1.44	.10	.67*	.56	.11
	97-3-1	65.30	13.20	1.76	4.26	3.11	1.00	2.88	.79	.87	6.78	.28	3.59*	2.70	.21
	108-8-2	58.60	13.85	5.86	.72	5.60	.95	4.40	.40	.80	8.78	.01	5.13	3.46	.19
	108-8-3	61.00	17.70	4.29	2.89	1.14	1.31	4.21	.40	.92	6.11	.036	1.84*	3.69	.54
Indiana	67-1-1	57.65	26.50	1.17	.36	.05	.45	2.80	.40	1.47	9.09	.042	1.46	6.29	1.34
Jefferson	63-9-1	66.20	18.30	1.32	.99	.12	.31	1.39	.34	1.36	9.63	.50	5.42*	3.38	.33
	64-3-1	60.80	24.55	1.71	.46	.12	.45	2.30	.25	1.34	8.00	.29	5.95*	.90	.86
Juniata	126-8-1	64.80	14.70	4.99	1.37	1.94	.95	3.43	.58	.71	6.50	1.41	3.55*	.84	.60
	126-8-3	63.30	14.00	5.47	1.39	3.77	1.00	3.03	.46	.86	6.73	.020	3.37*	3.10	.24
Lancaster	158-6-1	62.00	15.70	5.68	1.77	.04	1.58	3.77	.57	.93	7.92	.010	.66	7.26	
	168-2-4	63.10	16.30	7.84	.20	.40	1.54	2.44	.30	.83	7.00	.006	.26	5.89	.85
	168-3-1	61.00	16.50	4.23	3.22	.14	2.03	3.99	1.35	.90	6.60	.012	.95	5.65	
	168-3-2	62.90	16.60	5.50	2.07	.07	1.87	3.78	.79	.86	5.54	.010	.33	5.21	
	168-8-3	62.40	16.10	5.32	.61	.12	1.60	7.58	.48	.72	5.06	.012	.40	4.66	
	168-8-5	55.20	16.40	11.39	.12	.18	.73	6.60	.60	.77	7.97	.014	.92	5.26	1.79
	178-1-1	62.30	16.50	6.76	1.76	.08	1.75	3.90	.35	.82	5.76	.01	.48	5.10	.18
	178-4-2	68.50	13.90	6.10	.77	.08	1.28	2.85	.24	.68	5.44	.020	.57	4.87	
	178-8-4	71.35	13.00	4.88	.38	.08	.83	4.37	.22	.45	4.39	.016	.33	4.06	
	179-7-2	56.80	22.90	3.93	4.56	.09	.87	3.62	.51	1.23	5.44	.15	3.37*	1.92	
	188-4-1	75.00	15.70	.61	.64	.05	.40	1.75	.07	.93	4.78	.004	.15	4.60	.03
Lawrence	5-1-3	52.50	25.80	3.86	.76	.69	.82	2.04	.25	1.45	11.82	1.26	1.76*	10.06	2.49
	5-1-5	58.80	19.15	6.04	1.37	.29	1.08	3.11	.37	1.13	7.65	.084	3.17*	4.48	1.26
	5-3-4A	58.80	19.72	6.30	1.98	.19	1.34	3.19	.52	.95	6.99	.082	2.10*	4.89	.87
	5-3-4B	59.60	19.85	5.01	2.12	.23	1.40	3.28	.62	1.00	6.84	.052	1.86*	4.98	.72
	5-5-1	65.40	22.70	1.21	.38	.10	.47	2.42	.26	1.14	5.88	.015	2.61*	3.27	.91
	5-5-2	61.60	19.15	3.31	2.74	.48	1.07	3.31	.33	1.05	6.94	.19	2.55*	4.39	.73
Lebanon	157-3-4	64.30	14.45	5.45	2.30	.21	1.71	4.16	.66	1.02	5.69	.010	.66	5.03	
	157-6-1A	60.00	19.70	5.97	2.46	.07	.98	5.00	.52	.82	4.41	.004	.26	4.15	
	157-6-1B	62.50	17.05	5.38	1.77	.11	1.34	6.00	.26	.95	4.58	.008	.33	4.25	
	157-6-1C	61.40	17.30	6.42	1.44	.12	1.19	5.10	.55	.88	5.53	.01	.40	4.76	.37

	157-6-2	57.50	19.60	7.23	1.77	.19	1.20	4.08	.43	1.02	6.94	.014	.55	6.39	
	157-6-3	57.00	20.94	8.01	1.04	.12	.93	4.10	.83	.92	6.08	.01	.26	4.97	.85
	167-1-1	59.70	17.05	7.96	.60	.23	1.46	5.10	.80	.92	6.13	.01	.51	4.96	.66
	167-1-2	58.80	17.40	5.63	1.68	.79	1.54	4.20	1:57	.95	7.38	.008	1.72	4.23	1.43
Lehigh	196-1-1A	61.40	17.20	7.30	.77	.07	1.40	4.32	.24	.90	6.34	.010	.48	5.86	
	196-1-1B	60.80	13.50	5.77	1.38	.20	1.84	3.97	.82	.79	10.90	.030	.73	10.17	
	196-2-1	61.90	15.00	1.80	4.86	2.36	1.76	3.64	.90	.79	6.98	.36	4.28*	2.31	.03
	196-9-1	62.90	15.60	6.54	.46	.14	1.02	6.65	.64	.83	5.19	.028	.40	4.79	
Luzerne	184-6-1	65.30	17.10	6.58	.84	.13	1.01	3.68	.27	.85	4.19	.016	.22*	3.30	.65
	185-1-1	64.30	16.90	7.12	.72	.08	.77	4.05	.40	.95	4.68	.01	.26	4.30	.12
Lycoming	134-1-1	66.60	15.90	4.16	2.58	.20	1.16	3.09	1.04	.92	4.30	.022	.53*	3.77	.47
Monroe	215-1-1	61.30	17.50	1.97	4.48	1.67	1.30	3.75	.87	.90	6.24	.42	3.29*	2.50	.03
Montgomery	197-3-1	62.50	14.50	4.23	1.46	2.83	1.76	4.10	1.25	.78	6.55	.010	1.46	5.09	
	208-1-1	64.20	16.50	5.62	1.38	.40	1.82	2.30	2.98	.93	3.84	.008	.15	3.69	
Northampton	205-6-1	61.30	14.20	2.58	3.68	3.57	1.96	3.40	1.57	.80	6.92	.62	5.97	.90	.05
	205-8-2	64.40	15.50	5.69	1.54	.12	1.83	3.92	.75	.86	5.33	.022	.48	4.85	
	215-4-1	61.10	14.40	2.69	3.52	3.23	2.03	3.48	1.33	.74	7.48	.86	2.86	4.55	.07
	215-7-2	65.50	15.55	5.29	1.37	.33	1.60	3.86	.73	.77	4.96	.04	1.35*	3.53	.04
Northumberland	146-4-4	63.00	17.60	4.75	2.48	.07	1.05	3.70	.90	1.01	5.42	.02	2.42	2.59	.41
	146-5-2	64.10	16.45	5.96	1.54	.12	1.83	3.92	.75	.86	4.89	.012	.33	4.56	
	146-5-3	65.80	16.45	5.39	1.28	.30	1.56	3.10	.93	.93	4.23	.006	.26	3.41	.56
	155-8-1	59.20	25.70	.87	.76	.02	.39	4.03	.29	1.01	7.71	.20	4.66*	3.05	.36
Perry	127-4-1	62.10	17.75	5.58	1.68	.36	1.27	4.15	.70	.96	5.42	.02	.44	4.67	.31
	127-4-3	46.00	10.20	1.88	1.82	16.75	1.66	3.08	.25	.48	17.88	.024	14.49*	2.98	.39
	137-4-1	61.50	18.60	6.10	1.44	.19	.96	3.60	.45	.94	6.20	.02	.66	4.70	.84
Pike	213-4-1	62.10	18.80	5.80	2.43	.08	1.08	4.23	.49	.99	3.95	.016	.22*	3.65	.06
	233-4-1	66.90	15.70	2.74	4.10	.20	1.04	3.02	.95	.92	4.41	.016	1.32*	2.66	.41
Schuylkill	166-4-2	61.40	25.20	.61	.61	.02	.43	3.17	.48	1.14	6.93	.008	.51	6.42	
	175-7-1	54.00	15.45	3.19	2.15	.07	.57	3.22	.50	1.05	19.75	.13	11.74	8.00	
	176-1-1	46.62	15.34	.73	1.20	.06	.45	2.42	.31	1.20	31.66	.29	2.60*	6.59	1.31
	176-2-3	51.40	21.20	1.48	1.24	.12	.62	3.48	.68	1.30	18.44	.20	4.29*	.30	1.60
	176-5-2	59.10	20.00	6.34	.61	.02	.67	4.54	.58	.99	7.08	.026	2.16	4.92	
	185-7-2A	47.80	15.45	2.29	1.22	.08	.48	2.60	.31	1.16	28.57	.52	.30*	2.95	1.01

* CO_2 recalculated from CO_3=.

Table 8—*Chemical analyses of shale and clay samples (continued).*

County	Sample Number	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	K_2O	Na_2O	TiO_2	L.O.I.	S	CO_2	comb H_2O	H_2O @ 120°C
Somerset	49-9-1	52.60	18.87	3.69	3.60	4.10	1.76	2.40	.45	.82	11.66	.52	3.96	6.62	1.03
	59-5-3	46.40	35.70	.55	.59	.09	.18	.99	.35	2.29	12.85	.018	.84	12.01	
	59-6-1	55.00	19.85	7.71	1.28	.13	1.33	3.40	.78	.95	9.39	.19	3.48	4.35	1.56
	59-6-2	51.40	18.25	5.75	2.32	3.45	1.56	3.20	.65	.83	12.55	1.23	10.94		1.79
	59-7-1A	61.20	24.40	.55	.59	.10	.25	1.75	.33	1.70	9.06	.34	1.06	8.00	
	59-7-1B	60.30	27.00	.35	.45	.04	.04	.35	.12	1.56	9.73	.10	1.14	8.59	
	57-11-4	69.20	11.40	3.93	.61	3.30	.68	1.93	.27	.82	7.85	.018	3.73*	3.13	.97
	69-2-1	59.10	28.00	.19	.44	.06	.07	.10	.38	1.60	9.97	.21	.70	8.62	.65
Susquehanna	192-5-1	62.55	18.20	5.79	2.28	.15	.88	4.49	.53	1.01	4.10	.014	.22*	3.53	.34
Union	144-5-1	60.65	19.70	3.21	4.26	.20	1.35	3.96	.35	.95	5.32	.045	.82*	4.50	.44
Washington	8-5-2	54.00	19.95	.65	6.92	3.10	1.65	3.12	.78	.83	8.98	.23	2.85*	6.13	.90
	8-6-1	53.60	19.00	3.77	5.55	1.25	1.49	3.18	.57	.94	10.60	.26	4.36*	6.24	1.02
	18-1-1A	60.70	20.10	5.29	1.37	.77	1.06	2.82	.62	.99	6.25	.028	.74*	5.51	1.79
	18-1-1B	58.20	20.70	7.66	.61	.67	1.02	2.89	.63	.93	6.67	.028	.67*	6.00	2.31
	18-6-3	59.65	20.00	5.58	1.67	.10	.96	2.93	.66	1.04	7.37	.18	1.92*	5.45	1.63
	28-4-1	56.90	20.90	5.32	1.22	1.97	1.11	3.20	.57	.93	7.85	.035	1.41*	6.44	1.27
	28-5-2	53.60	20.25	6.61	3.19	.47	1.11	3.02	.31	.97	10.44	.14	7.13*	3.31	.76
Wayne	202-8-1	62.75	18.50	6.14	1.75	.24	1.50	3.04	.62	1.00	4.42	.018	.15*	3.90	.35
Westmoreland	47-8-1A	59.00	26.91	.98	.96	.08	.50	1.56	.42	1.76	7.75	.051	1.06	6.02	.67
	47-8-1B	60.40	24.60	1.55	1.00	.07	.63	2.80	.37	1.23	7.32	.024	.99	5.68	.65
	48-2-1	63.80	23.10	.85	.52	.03	.57	3.05	.32	1.10	6.60	.010	.48	5.09	1.03
York	148-8-1	53.31	19.05	8.37	1.12	1.80	2.65	3.65	1.45	.92	7.64	.008	1.06	5.07	1.51
	149-11-1	56.50	28.85	.83	.53	.02	.62	4.52	.26	1.07	6.76	.019	1.49*	5.27	.07
	158-9-1	70.70	17.15	1.42	1.00	.02	.79	3.82	.18	1.10	3.77	.012	.33	3.44	
	159-1-1	60.50	18.70	6.95	.32	.06	1.54	3.95	1.88	.96	5.08	.016	.48	4.16	.48
	159-1-2	64.40	18.65	4.45	1.00	.04	.67	4.60	.22	.98	4.94	.008	.15	4.79	
	159-1-3	65.80	16.90	5.50	.92	.05	.57	2.64	.28	1.26	6.04	.010	.33	5.71	
	159-1-4	49.50	25.30	9.50	.54	.03	.43	4.03	2.10	1.36	7.20	.014	.77	6.43	
	169-12-2	55.20	19.75	5.20	6.69	.25	.99	3.42	.49	1.08	6.92	.058	5.28*	1.48	.10

* CO_2 recalculated from CO_3=.

Table 9.—Use for shales and clays by geologic units (continued)

GEOLOGIC AGE	GEOLOGIC UNIT: Group or Formation	GEOLOGIC UNIT: Horizon	NUMBER OF SAMPLES SHOWING A POTENTIAL FOR THE INDICATED USE*																										
												REFRACTORIES						LIGHTWEIGHT AGGREGATE											
																		Rotary kiln											
			Total number of samples	Brick	Decorative brick	Tile	Floor tile	Drain tile	Chimney flue tile	Sewer pipe	Low duty	Intermediate duty	Super duty	High duty	Foundry and Steelworks refractories	Refractory mortar	Fair	Good	Excellent	Sintered aggregate	Artware	Pottery	Filler	Pigmenting material	Fluxing material	White cement	Paper coater (low-grade)	No uses
Devonian	Catskill Fm.		6	3 /			2											1		2								1
	marine beds		1	1																								
	Hamilton Gp.	undifferentiated	2	2		1												1										
	Mahantango Fm.	undifferentiated	6	1-2		1	1											2 /		1								
		upper member	1	1		1	1										1											
		Frame Member	1	1		1	1											1										
		Gender Run Member	1	1		1												1										
	Marcellus Fm.		3	1																1								1
	Oriskany Fm.		1								1					1												
	Total Devonian		22	7 1		1 4	2 3				1					1	1	3 1		2 3								2
Silurian	Wills Creek Fm.		2																									2
	Bloomsburg Fm.		2	1																								1
	Rose Hill Fm.		3	2			1													1								
	Total Silurian		7	3			1													1								2
Ordovician	Martinsburg Fm.		26	11 6		4	3										1 1	11	2	1 3								
	Cocalico Fm		5	1-1																								3
	Conestoga Fm.		2	2																								
	Total Ordovician		23	14 10		4	3										1 1	11	2	1 3								3
Cambrian	Conococheague Gp	undifferentiated	1	1																				1				
	Gatesburg Fm.		1		1	1			1				1								1	1	1	1		1	1	
	Ledger Fm.		2	1		1														1				1				
	Kinzers Fm.		1	1			1	1																				
	Harpers Fm		3		2	2					1																	1
	Chickies Fm.		4	1											1								1					3
	Total Cambrian		12	4	2 1	4	1	1	1		1		1		1					1	1	1	2	2 /		1	1	4
Probably lower Paleozoic	Peach Bottom Slate		2																	2								
	Wissahickon Fm.		1						1		1												1					
Precambrian			2		1	1																	1					
		Total for all ages	131	56 26	12 1	27 3	8 14	4 1	10 4	1	3 4	3	2	3	1	1	10 1	28 1	2	4 10	3	4	4	3 1	1	1	1	16

* Nonitalicized figure indicates a potential, italicized figure indicates possible potential

its.

OF SAMPLES SHOWING A POTENTIAL FOR THE INDICATED USE *

Sewer pipe	REFRACTORIES				Foundry and Steelwork refractories	Refractory mortar	LIGHTWEIGHT AGGREGATE				Artware	Pottery	Filler	Pigmenting material	Fluxing material	White cement	Paper coater (low-grade)	No uses
							Rotary kiln											
	Low duty	Intermediate duty	High duty	Super duty			Fair	Good	Excellent	Sintered aggregate								
										/								
								1						/	/			
										1								
								1		1				/	/			
							1											
										1-3								
								1										
							2			1								
										/								
							1											
							1											
							1	1										
							1	2										
										/								
								2		1								
	2-2	1	2	1								1						1
							1	1										
1	1	4																
	1										1	1						
										2								2
	1										1	1						1
				2														
	1																	
1	4-4	5	2	3			7	7		6	2	3						4

USES LISTED BY GEOLOGIC UNIT

A complete study of the shales and clays of Pennsylvania would be able to show the potentials of each of the State's geologic units. The 151 samples tested in this study represent a small fraction of the sampling required to achieve such a purpose, and meaningful correlations between unit and use cannot be made.

The use patterns developed for the geologic units are shown in Table 9. Positive results indicate a potential for that use in at least some part of the geologic unit and, in some cases, suggest units which are worth further investigation. Negative results, on the other hand, are not very reliable because of the limited number of samples tested. They should not be used to eliminate units from further consideration.

In Table 9, the geologic units are presented in order of geologic age, beginning with the youngest at the top. This list does not represent a complete geologic column but includes only the units sampled during this study.

USES LISTED BY LOCATION

Table 10 is divided into different use categories. Listed by county under each use are the samples that indicate a potential or possible potential according to test results. Each sample is identified by sample number and geologic unit. This table serves as a guide to raw materials for a specific use in a particular county or region. The county location and sample number serve as cross references to the sample data sheets which were presented earlier in the report.

EVALUATION OF ANALYTICAL DATA

GENERAL STATEMENT

BY D. M. LAPHAM

A large number of physical, chemical, and mineralogical variables have been measured on both the raw sample and the fired product in the hope that criteria can be established for rapid and accurate evaluation of Pennsylvania shales and clays. The correlations presented in this chapter are primarily concerned with the practical aspects of clay materials utilization; however, several are discussed which are of a more fundamental geological nature. In general, complex multi-variant analysis has been avoided because empirical use relationships are desired rather than the more theoretical relationships arising from an inter-

Table 10—*Shale and clay samples listed by potential use by county.*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
			Brick		
Adams	139-6-3	Triassic		New Oxford	
	139-6-4	Triassic		New Oxford	
	139-9-2	Cambrian		Kinzers	
Allegheny	16-9-2	Pennsylvanian		Conemaugh	Ames
	16-9-3	do		do	Ames
	17-2-1	do		do	below Pittsburgh limestone
	26-4-1	do		do	Pittsburgh red beds
Bedford	78-9-2*	Devonian	Hamilton	Marcellus	
	88-8-1A*	do	do	Mahantango	Gander Run Member
	88-8-1B*	do	do	do	Frame Member
	88-8-1C*	do	do	do	upper member
Berks	167-2-4*	Ordovician		Martinsburg	
	177-2-1*	do		do	
	177-6-2*	do		do	
	186-8-2	do		do	
	186-9-1	do		do	
	187-1-2	do		do	
	187-4-3	Cambrian	Conococheague		
	187-8-1	Triassic		Brunswick	
Bucks	207-2-1	Triassic		Brunswick	
Butler	15-2-1	Pennsylvanian	Allegheny	Kittanning	middle Kittanning
	25-5-2*	do	do	Freeport	lower Freeport underclay
Clarion	44-4-2B*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning shale
	44-4-2C	do	do	do	do
	44-4-3	do	do	Clarion	upper Clarion shale
	44-8-4*	do	do	Kittanning	middle Kittanning

Clearfield	85-3-4	Pennsylvanian	Allegheny	Kittanning	middle Kittanning
Cumberland	127-9-1	Ordovician		Martinsburg	
	138-1-1	do		do	
Dauphin	146-7-1*	Mississippian		Mauch Chunk	
	148-3-1*	Ordovician		Martinsburg	
Huntingdon	97-3-1*	Devonian	Hamilton	Mahantango	
	108-8-2*	Silurian		Bloomsburg	
	108-8-3*	do	Clinton	Rose Hill	
Jefferson	64-3-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Lancaster	168-2-4	Triassic		New Oxford	
	168-8-3	Ordovician		Conestoga	
	168-8-5	Cambrian		Ledger	
	178-1-1	Ordovician		Cocalico	
	178-4-2*	do		do	
	188-4-1	Cambrian		Chickies	
Lawrence	5-1-3	Pennsylvanian	Allegheny	Kittanning	middle Kittanning underclay
	5-1-5	do	do	do	lower Kittanning shale
	5-3-4A*	do	do	do	middle Kittanning shale
	5-3-4B	do	do	do	do
	5-5-2	do	do	Clarion	upper Clarion
Lebanon	157-3-4	Ordovician		Martinsburg	
	157-6-1A*	do		do	
	157-6-1B*	do		do	
	157-6-1C*	do		do	
	157-6-2*	do		do	
	157-6-3	do		do	
	167-1-1	do		do	
	167-1-2	do		do	
Lehigh	196-1-1A	Ordovician		Martinsburg	
	196-1-1B	do		do	
	196-9-1	Quaternary			
Luzerne	184-6-1*	Mississippian		Mauch Chunk	
	185-1-1	do		do	

* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
Brick (continued)					
Montgomery	197-3-1	Triassic		Brunswick	
	208-1-1*	do		do	
Northampton	205-8-2*	Ordovician		Martinsburg	
Northumberland	146-4-4	Devonian	Hamilton	Mahantango	marine beds
	146-5-2	do			
	146-5-3	do		Catskill	
Perry	127-4-1*	Silurian		Rose Hill	
	137-4-1*	Devonian	Hamilton	Mahantango	
Pike	213-4-1	Devonian		Catskill	
	233-4-1	do	Hamilton		
Schuylkill	176-5-2	Devonian	Hamilton		
Somerset	49-9-1*	Pennsylvanian		Conemaugh	Brush Creek shale
	59-6-1	do		do	Friendsville shale
	59-6-2	do		do	Ames shale
	59-11-4	Quaternary			
Susquehanna	192-5-1*	Devonian	Susquehanna	Catskill	
Washington	8-5-2	Permian		Greene	
	8-6-1	Permian & Pennsylvanian		Washington	
	18-1-1A	do		do	
	18-1-1B	do		do	
	18-6-3	Pennsylvanian		Monongahela	Uniontown
	28-4-1	Permian & Pennsylvanian		Washington	

Wayne	202-8-1	Devonian		Catskill	
York	148-8-1	Triassic		New Oxford	
	159-1-1	Ordovician		Conestoga	

Decorative Brick

Adams	129-2-1	Precambrian schist			
Blair	87-6-1*	Cambrian		Gatesburg	
Butler	15-2-1A*	Pennsylvanian	Allegheny	Kittanning	middle Kittanning underclay
Clarion	44-4-2A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Clearfield	85-2-3*	Pennsylvanian	Allegheny	Clarion	Clarion underclay
	85-3-5	do	do	do	do
	85-5-2*	do	do	Kittanning	middle Kittanning underclay
	85-6-1	do	do	do	lower Kittanning underclay
	95-4-1	do	do	do	upper Kittanning underclay
Cumberland	138-7-2	Cambrian		Harpers	
	138-7-2A	do		do	
Fayette	49-4-1A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Indiana	67-1-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Lawrence	5-5-1*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Schuylkill	166-4-2	Pennsylvanian	Pottsville		
Somerset	59-7-1A	Pennsylvanian	Allegheny	Clarion	Clarion underclay
Westmoreland	47-8-1A*	Pennsylvanian	Pottsville	Mercer	Mercer underclay
	47-8-1B*	do	do	do	
	48-2-1	do	Allegheny	Clarion	Brookville clay

* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
			Tile		
Adams	129-2-1	Precambrian schist			
Allegheny	16-9-3	Pennsylvanian		Conemaugh	Ames
Bedford	88-8-1A*	Devonian	Hamilton	Mahantango	Gander Run Member
	88-8-1B*	do	do	do	Frame Member
	88-8-1C*	do	do	do	upper member
Blair	87-6-1	Cambrian		Gatesburg	
Bucks	207-2-1	Triassic		Brunswick	
Butler	15-2-1A*	Pennsylvanian	Allegheny	Kittanning	middle Kittanning underclay
Clarion	44-4-2A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
	44-4-2C	do	do	do	lower Kittanning shale
	44-4-3	do	do	Clarion	upper Clarion shale
Clearfield	85-3-5	Pennsylvanian	Allegheny	Clarion	Clarion underclay
	85-6-1	do	do	Kittanning	lower Kittanning underclay
	95-4-1	do	do	do	upper Kittanning underclay
Cumberland	127-9-1	Ordovician		Martinsburg	
	138-1-1	do		do	
	138-7-2	Cambrian		Harpers	
	138-7-2A	do		do	
Fayette	49-4-1A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Indiana	67-1-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Jefferson	64-3-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay

Lancaster	168-8-5	Cambrian		Ledger	
Lebanon	167-1-1 167-1-2	Ordovician do		Martinsburg do	
Lehigh	196-9-1	Quaternary			
Luzerne	185-1-1	Mississippian		Mauch Chunk	
Perry	137-4-1*	Devonian	Hamilton	Mahantango	
Schuylkill	176-5-2	Devonian	Hamilton		
Somerset	59-11-4	Quaternary			
Washington	28-4-1	Permian and Pennsylvanian		Washington	
Westmoreland	48-2-1	Pennsylvanian	Allegheny	Clarion	Brookville clay
York	148-8-1	Triassic		New Oxford	

Floor Tile

Adams	139-9-2*	Cambrian		Kinzers	
Allegheny	16-9-2* 17-2-1	Pennsylvanian do		Conemaugh do	Ames below Pittsburgh limestone
Bedford	88-8-1B* 88-8-1C*	Devonian do	Hamilton do	Mahantango do	Frame Member upper member
Berks	177-2-1* 177-6-2*	Ordovician do		Martinsburg do	
Butler	15-2-1*	Pennsylvanian	Allegheny	Kittanning	middle Kittanning
Huntingdon	97-3-1*	Devonian	Hamilton	Mahantango	
Lancaster	168-2-4	Triassic		New Oxford	

* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
		Floor Tile (continued)			
Lawrence	5-1-5	Pennsylvanian	Allegheny	Kittanning	lower Kittanning shale
	5-3-4B	do	do	do	middle Kittanning shale
	5-5-2*	do	do	Clarion	upper Clarion
Lehigh	196-1-1B*	Ordovician		Martinsburg	
Luzerne	184-6-1	Mississippian		Mauch Chunk	
Perry	127-4-1	Silurian	Clinton	Rose Hill	
Pike	213-4-1	Devonian		Catskill	
Somerset	59-6-1*	Pennsylvanian		Conemaugh	Friendsville shale
	59-6-2*	do		do	Ames shale
Washington	8-5-2*	Permian		Greene	
	8-6-1*	Permian and Pennsylvanian		Washington	
	18-1-1A	do		do	
	18-1-1B	do		do	
	18-6-3	Pennsylvanian		Monongahela	Uniontown
Wayne	202-8-1	Devonian		Catskill	
		Drain Tile			
Adams	139-9-2	Cambrian		Kinzers	
Fayette	49-4-1A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Schuylkill	166-4-2	Pennsylvanian	Pottsville		

Somerset	59-11-4	Quaternary			
Westmoreland	47-8-1A*	Pennsylvanian	Pottsville	Mercer	Mercer underclay
	47-8-1B*	do	do	do	

Chimney Flue Tile

Blair	87-6-1	Cambrian		Gatesburg	
Clarion	44-4-2A*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Clearfield	85-2-3	Pennsylvanian	Allegheny	Clarion	Clarion underclay
	85-3-5	do	do	do	do
	85-6-1	do	do	Kittanning	lower Kittanning underclay
Fayette	49-4-1A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Indiana	67-1-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Lawrence	5-5-1*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Schuylkill	166-4-2	Pennsylvanian	Pottsville		
Somerset	59-7-1A*	Pennsylvanian	Allegheny	Clarion	Clarion underclay
Westmoreland	47-8-1A	Pennsylvanian	Pottsville	Mercer	Mercer underclay
	47-8-1B	do	do	do	
	48-2-1	do	Allegheny	Clarion	Brookville clay
York	149-11-1*	Lower Paleozoic		Wissahickon	

Refractories

Super duty

Clearfield	85-5-6	Pennsylvanian	Pottsville		Mercer
Fayette	49-4-1B	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Somerset	59-5-3	Pennsylvanian	Pottsville		Mercer

* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
Refractories (continued)					
High duty					
Blair	87-6-1 (beneficiated)	Cambrian		Gatesburg	
	87-6-1	do		do	
Clarion	44-2-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Fayette	49-4-1A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Intermediate duty					
Clearfield	85-2-3	Pennsylvanian	Allegheny	Clarion	Clarion underclay
	85-3-5	do	do	do	do
	85-6-1	do	do	Kittanning	lower Kittanning underclay
Somerset	59-7-1B	Pennsylvanian	Allegheny	Clarion	Clarion underclay
	69-2-1	do	do	do	Mt. Savage clay
Low duty					
Clarion	44-4-2A*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Cumberland	138-7-2A	Cambrian		Harpers	
Huntingdon	96-9-1	Devonian		Oriskany	
Indiana	67-1-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Jefferson	64-3-1*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Lawrence	5-5-1	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay

Schuylkill	166-4-2*	Pennsylvanian	Pottsville		
Somerset	59-7-1A	Pennsylvanian	Allegheny	Clarion	Clarion underclay
Westmoreland	47-8-1A*	Pennsylvanian	Pottsville	Mercer	Mercer underclay
	48-2-1	do	Allegheny	Clarion	Brookville clay
York	149-11-1	Lower Paleozoic		Wissahickon	

Lightweight Aggregate (Rotary Kiln)

Adams	139-4-1 *g*	Triassic		Gettysburg	Heidlersburg Member
Allegheny	16-9-2 *f*	Pennsylvanian		Conemaugh	Ames
Bedford	88-8-1A *g*	Devonian	Hamilton	Mahantango	Gander Run Member
	88-8-1B *g*	do	do	do	Frame Member
	88-8-1C *f*	do	do	do	upper member
Berks	177-2-1* *f*	Ordovician		Martinsburg	
	186-9-1 *g*	do		do	
	187-1-2 *f*	do		do	
Butler	25-5-1 *g*	Pennsylvanian		Conemaugh	Mahoning
	25-5-3A *f*	do		do	do
Carbon	195-5-2 *g*	Devonian	Hamilton	Mahantango	
Clarion	44-4-2B *g*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning shale
	44-4-3 *f*	do	do	Clarion	upper Clarion shale
	44-8-4 *f*	do	do	Kittanning	middle Kittanning
Cumberland	127-9-1 *g*	Ordovician		Martinsburg	
	128-2-1 *g*	Ordovician		do	
	138-1-1 *g*	do		do	
Franklin	108-6-1 *g*	Ordovician		Martinsburg	

e—excellent lightweight aggregate; *f*—fair; *g*—good.
* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit*		
			Group	*Formation*	*Horizon*
Lightweight Aggregate (continued)					
Lawrence	5-1-5 *g*	Pennsylvanian	Allegheny	Kittanning	lower Kittanning shale
	5-3-4A *g*	do	do	do	middle Kittanning shale
	5-3-4B *g*	do	do	do	do
	5-5-2 *g*	do	do	Clarion	upper Clarion
Lebanon	157-3-4 *e*	Ordovician		Martinsburg	
	167-1-1 *g*	do		do	
	167-1-2 *g*	do		do	
Lehigh	196-1-1B *e*	Ordovician		Martinsburg	
	196-2-1 *g*	do		do	
Lycoming	134-1-1 *g*	Devonian	Hamilton	Mahantango	
Monroe	215-1-1 *g*	Devonian	Hamilton	Mahantango	
Northampton	205-6-1 *g*	Ordovician		Martinsburg	
	215-4-1 *g*	do		do	
	215-7-2 *g*	do		do	
Perry	137-4-1 *g*	Devonian	Hamilton	Mahantango	
Pike	233-4-1 *g*	Devonian	Hamilton		
Somerset	49-9-1 *f*	Pennsylvanian		Conemaugh	Brush Creek shale
	59-6-1 *f*	do		do	Friendsville shale
	59-6-2 *f*	do		do	Ames shale
Washington	8-5-2 *f*	Permian		Greene	
	28-5-2 *g*	Pennsylvanian		Monongahela	above Pittsburgh coal
Wayne	202-8-1 *g*	Devonian		Catskill	

Allegheny	16-9-3*	Pennsylvanian		Conemaugh	Ames
	26-4-1*	do		do	Pittsburgh red beds
Berks	177-6-2*	Ordovician		Martinsburg	
	186-8-2	do		do	
Carbon	195-2-3	Devonian		Catskill	
	195-7-1*	do	Hamilton	Marcellus	
Clarion	44-4-2C*	Pennsylvanian	Allegeheny	Kittanning	lower Kittanning shale
Erie	1-5-1*	Quaternary			
Huntingdon	97-3-1*	Devonian	Hamilton	Mahantango	
Lancaster	168-8-5*	Cambrian		Ledger	
	179-7-2*	Lower Paleozoic		Beach Bottom	
Lawrence	5-1-3*	Pennsylvanian	Allegheny	Kittanning	middle Kittanning underclay
Lebanon	157-6-1A*	Ordovician		Martinsburg	
	157-6-1B*	do		do	
Schuylkill	176-2-3*	Pennsylvanian		Post Pottsville	
	185-7-2A*	do		do	
Susquehanna	192-5-1	Devonian	Susquehanna	Catskill	
Union	144-5-1*	Silurian	Clinton	Rose Hill	
Washington	8-6-1*	Permian and Pennsylvanian		Washington	
	18-1-1A	do		do	
	18-1-1B*	do		do	
	28-4-1*	do		do	
York	148-8-1*	Triassic		New Oxford	
	169-12-2*	Lower Paleozoic		Peach Bottom	

e—excellent lightweight aggregate; *f*—fair; *g*—good.
* possible potential

Table 10—*Shale and clay samples listed by potential use by county (continued).*

County	*Sample No.*	*Geologic Age*	*Geologic Unit* — *Group*	*Formation*	*Horizon*
Artware and Pottery, Filler, and Pigmenting Materials					
Pottery					
Clarion	44-4-2A	Pennsylvanian	Allegheny	Kittanning	lower Kittanning underclay
Artware and Pottery					
Schuylkill	166-4-2	Pennsylvanian	Pottsville		
Westmoreland	48-2-1	Pennsylvanian	Allegheny	Clarion	Brookville clay
Filler					
Adams	129-7-2	Precambrian schist			
Blair	87-6-1 (beneficiated sample)	Cambrian		Gatesburg	
Lancaster	188-4-1	Cambrian		Chickies	
York	149-11-1	Lower Paleozoic		Wissahickon	
Pigmenting Materials					
Berks	187-4-3* 187-8-1*	Cambrian Triassic	Conococheague	 Brunswick	
Blair	87-6-1	Cambrian		Gatesburg	
Lancaster	178-8-4	Cambrian		Ledger	

Other Uses

Fluxing Material					
Adams	139-4-1	Triassic		Gettysburg	Heidlersburg Member
White Cement, Ceramic Ware, Low Grade Paper Coater					
Blair	87-6-1	Cambrian		Gatesburg	
Refractory Mortar					
Huntingdon	96-9-1	Devonian		Oriskanny	
Sewer Pipe					
Jefferson	63-9-1	Pennsylvanian	Allegheny	Clarion	Clarion underclay
Foundry and Steelwork Refractories					
Lancaster	188-4-1	Cambrian		Chickies	

* possible potential

dependence of variables. Selected parameters have been plotted to determine range, average, and optimal values with respect both to use and rock type. Rock types, as used in this section, are based upon the restricted geological definitions given in the Glossary. Their selection was based upon previous published research (see References) and the experience of the authors involved although other factors are undoubtedly significant.

The following types of correlations with use and/or rock type are presented in detail in succeeding sections:

1. Geologic rock type
2. Mineralogical composition
3. Chemical composition
4. Selected physical properties tests on unfired material.

Texture, color, and grain size of the raw material have not been considered in detail, in part because of the difficulty of obtaining representative and accurate quantitative measurements.

Definitions of Use Categories for Correlation Purposes

For the purpose of plotting, use categories as given by the U. S. Bureau of Mines have been modified and are defined as follows:

1. Brick: a structural clay product excluding decorative and buff-burning bricks; sometimes referred to as common brick.
2. Tile: largely structural tile including floor (or quarry) tile and a group referred to as potential "tiles." Drain tiles have been included, but chimney flue tiles have been excluded except where otherwise specified. The latter were excluded because they are more similar to low-duty refractories than to other tiles. All samples potentially useful for chimney flue tile are also potential low-duty refractories.
3. Decorative brick: a structural clay product including face brick, buff brick, and other eye-pleasing brick colors.
4. Refractories: low-duty (or low grade), intermediate-duty (or intermediate grade), high-duty, and super-duty refractories which are defined by PCE. The last two grades have been plotted together as one category.
5. Lightweight aggregate: expandable material which might be suitable for the rotary-kiln process based on the quick-firing tests. Rock type, mineralogy, chemistry, pH, plasticity, and shrinkage correlations are based on bloating tests in a muffle kiln on an original five-pound sample and do not include the twenty-five 300-lb. bulk-sample results of rotary-kiln and concrete-block testing because the analyses were performed on the original samples and not on the bulk samples. The "fair"

category includes results listed as "acceptable." A certain amount of judgment was used to place a bloater in a particular grade. Plotted samples do not include sintered aggregate.

6. Sintered aggregate: expandable aggregate classified as poor on the basis of quick-firing tests; hence the number of samples reported to have this potential use are not representative of the total usable potential.

7. No Use: includes samples listed with no potential use, samples of possible or questionable use, washed or otherwise beneficiated samples, anthracite waste, pigment, sewer pipe, and filler unless otherwise specifically noted.

Correlation Limitations

The following limitations may affect the validity of the correlations presented in succeeding sections, although in most cases these limitations probably are not sufficient to distort the general conclusions nor to prevent their usefulness in the exploitation of potential clay materials deposits:

1. Even though great care was taken to collect a representative 10 lb. sample at each site, a margin of error may exist for the representation of an entire exposure.

2. Inaccuracy in the mineralogical, chemical, and physical properties tests may affect the results slightly. However, inaccuracies are probably within the limits of significant correlation (see Testing Procedures).

3. Some of the samples may not have been considered for all possible multiple uses, or their placement in a potential-use category may have relied too heavily on judgment. In either case, only correlations where there are few samples involved would be affected.

4. Correlations between two variables may actually be an oversimplification of a multiple interdependence of three or more variables. For example, shales may have a different component (C) range (i.e., quartz, CO_2, pH, etc.) for potentially good lightweight aggregate than slates for the same quality aggregate. In most cases the result of simplifying to binary correlations will be to enlarge the range of any one variable with respect to potential use.

Of the errors discussed, this one of multiple interdependence is potentially the most serious and the one most difficult to assess. Nevertheless, some confidence limit is possible. If there is any significant oversimplification in the correlation graphs, the most probable source of error will be in the influence of rock type (texture, color, cleavage or parting planes, grain size, porosity, etc.) on specific components (C), such as quartz or total iron content, for a specific potential use. For example, if the quartz range for good lightweight aggregate from shales differs from the range in slates, this will only be apparent if there are large numbers of samples

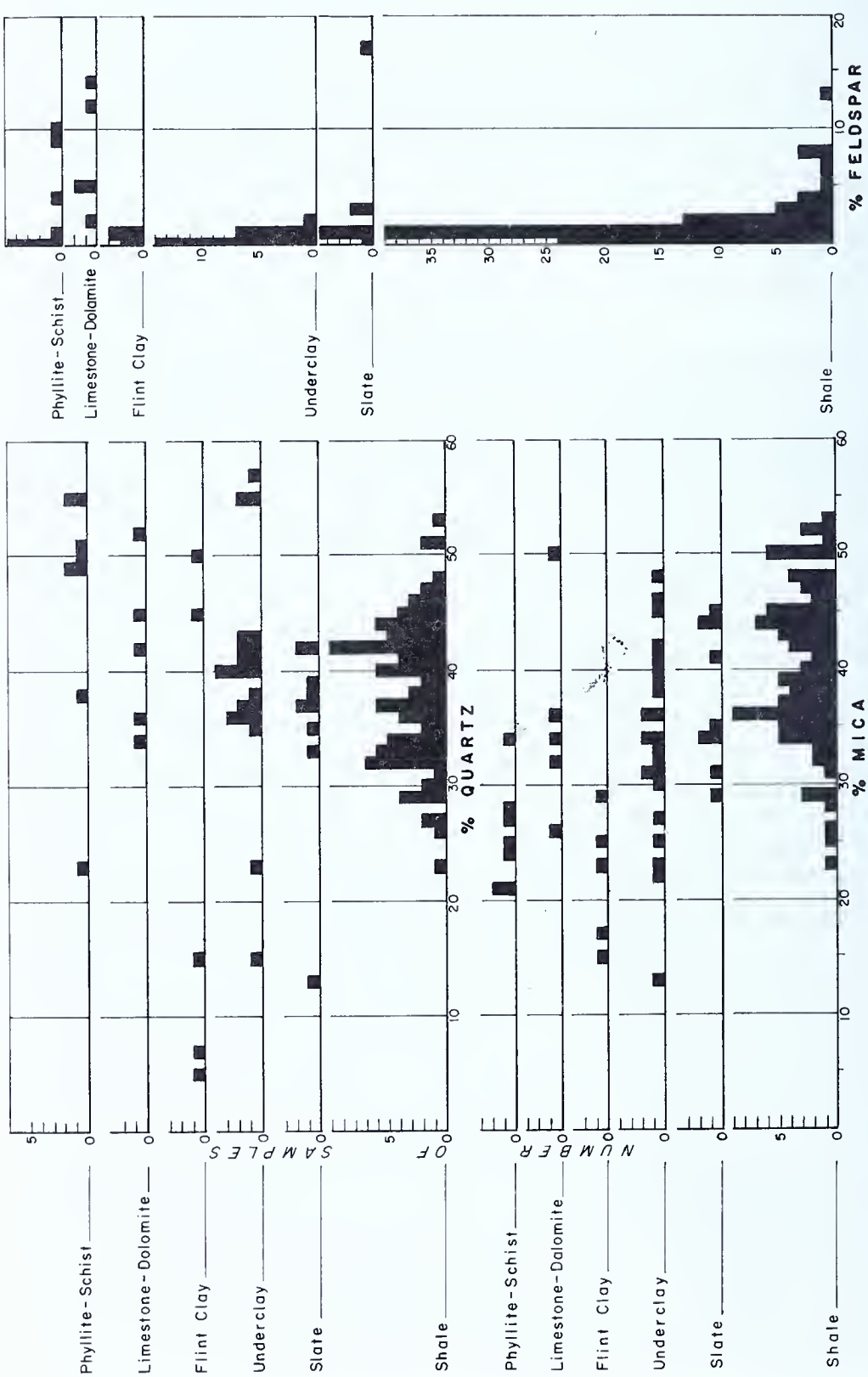


Figure 6. Histograms showing mineral composition of all rock types studied.

both above and below the quartz range in each rock type which were NOT potential sources of good lightweight aggregate. Thus, to express a strong theoretical confidence limit, each variable must be well bracketed by samples outside the usable range (use range) for each rock type.

Histograms illustrating the mineral variation in each rock type for all analyzed samples are shown in Figures 6 and 7. Similar histograms were made for pH and CO_2 (not shown). By comparing the ranges in these histograms with the binary graphs for mineralogy, pH, or CO_2 plotted against potential use, the number of samples which are below or above the use range for that component (C) in a particular rock type can be determined. Table 11 presents such a numerical expression of the confidence which may be placed upon the range of any one of these components (C). The rock types selected were those for which a potential use has been shown to exist (Fig. 13). A zero in any one box means that there were no samples of that particular rock type for which that component (C) was outside the use range. A positive number means that that number of samples exceeded the use range; a negative number designates samples below the use range, and a number without a sign designates a component (C) for which the lower range terminates at zero. For example, under the use heading of brick, a zero appears in the box opposite quartz indicating that there are no shales and no limestone-dolomite samples for which the quartz content lies outside the usable range; however, in underclays three samples contained quartz above the usable range (+3 in the table) and one sample below the usable range (–1 in the table). In general, a zero means that the range limits may not have been established. The higher the number, the more samples there are bracketing the range, and the greater is the confidence which can be placed upon the range for that particular binary correlation.

Although Table 11 presents the theoretical validity of two-component correlations, it is important to emphasize that given component (C) ranges actually may be correct even though no samples lie outside that range (i.e., a zero in Table 11). This may be the case because use of the interdependence table assumes that component (C) ranges are controlled by more than one factor, whereas actually many of these variables may be independent, at least as far as any potential use is concerned. Thus, for example, quartz content in lightweight aggregate may be more important than whether the quartz is present in a shale or a slate. That some of these components (C) may be independent of rock type is suggested by the figures under "brick" in Table 11. There are a large number of zeros here which might suggest that the correlations of these components (C) with brick are ill-defined. However, this is the category for which there are the largest number of analyzed samples and hence confidence in these correlations should be a maximum. A major

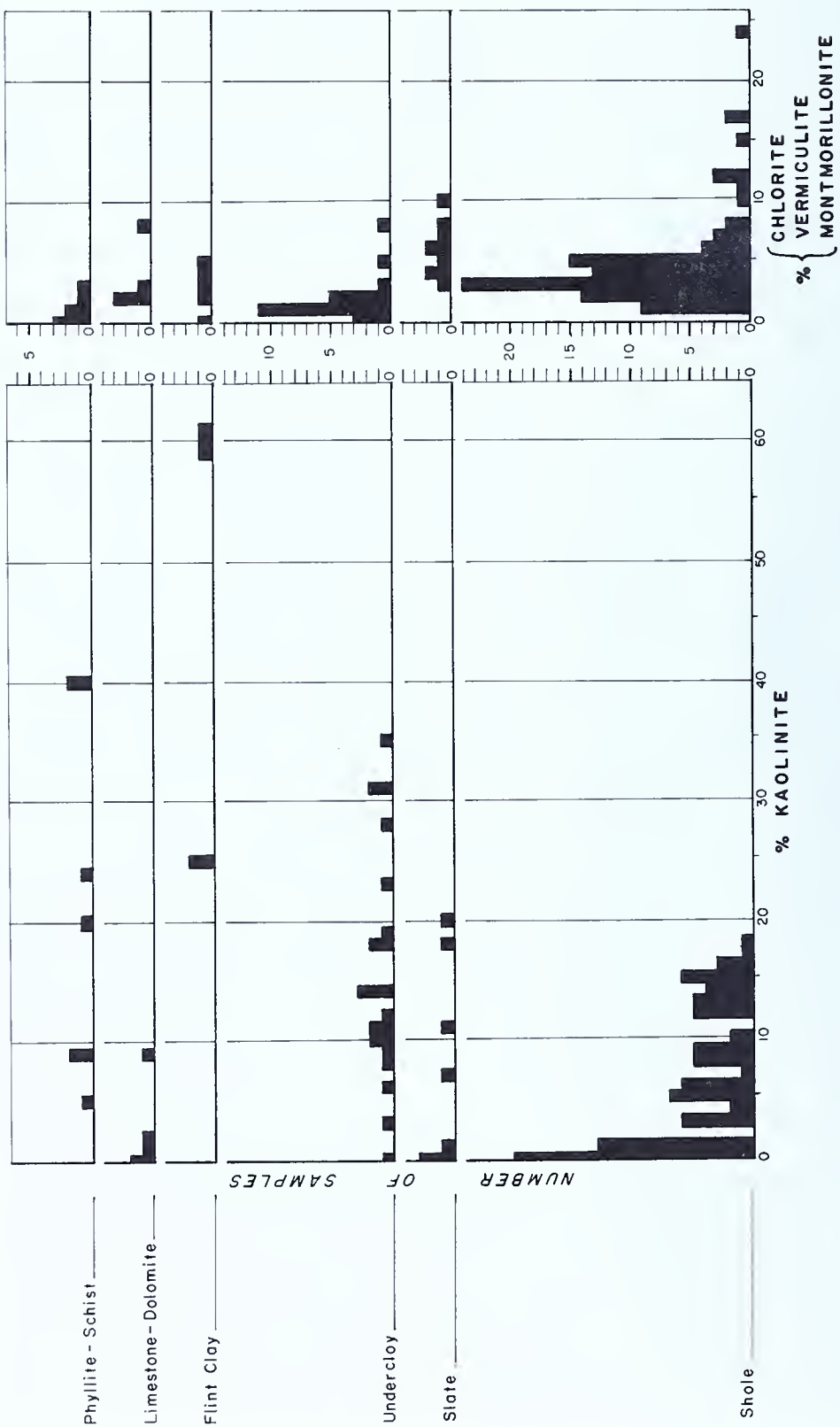


Figure 7. Histograms showing mineral composition of all rock types studied.

Table 11—*Validity of component (C) ranges for specific uses.*

	Brick				*Tile*				*Decor. Brick*		*Refractory*						*Lightweight Aggregate*				
											Low		*Intermed.*		*H. Super.*		*Fair*	*Good*		*Excellent*	
C	*sh*	*ls-dol*	*ucl*	*sl*	*sch*	*sh*	*ls-dol*	*ucl*	*sch*	*ucl*	*sch*	*ucl*	*ucl*	*fcl*	*ucl*	*fcl*	*sh*	*sh*	*sl*	*sh*	*sl*
Quartz	0	0	+3 –1	–1	0	0	0	0	0	0	0	–1	+3 –2	–3	+9	+2	+3 –4	+9 –4	–1	+19 –1	–1
Mica	+1 –1	0	–3	0	0	+1	0	0	0	+5	0	+5	+7 –1	0	+18	+1	+5 –8	–4	0	+5	0
Kaolinite	0	0	6	1	0	0	0	0	–1	–2	0	1	+2 –10	+3	–20	–2	+2 – 20	0	0	1	1
C-V-Mo	1	0	0	0	0	8	0	0	0	1	1	3	2	2	1	0	+7	+10	+2	+3 –9	0
Feldspar	0	0	0	0	0	0	0	0	1	0	3	1	1	0	0	0	+7 –24	10	1	–24	–1
pH	+1	0	0	0	0	+1	0	0	0	0	+1	+6 –2	+6 –2	–1	+7	0	+24 –32	–1	0	+6 –16	–3
CO_2	+3	0	0	0	0	+5	0	0	0	+4	–5	+3	+5 –4	–1	+3	0	+2 –14	+8	+1	+8	0

KEY

H. Super = high duty to super refractories.
sch = schist or phyllite.
sl = slate.
sh = shale.
ls-dol = residual clay on limestone or dolomite.
fcl = flint clay.
ucl = underclay.
C-V-Mo = chlorite, vermiculite, montmorillonite.

0 Component does not lie outside use range.
+ Component exceeds use range by stated no, of samples.
- Component is less than use range by stated no. of samples.
2 Component exceeds use range by stated no. of samples (low range end terminates at zero %).

reason for the occurrence of few samples outside any given use range, may be that the rock type has the same, limited range. Such a range cannot be bracketed. For such reasons, most of the correlations presented in the succeeding graphs are considered to be valid, or at least indicative of the trends of compositional variation within a specific use category.

CORRELATIONS

BY D. M. LAPHAM AND M. G. JARON

Mineralogical Correlations

Mineralogical composition has generally been assumed to be one of the most important factors in determining the use of a particular clay or shale unit, but has often been difficult to assess because of the difficulty of accurate mineral quantification. The X-ray method described in this report is considered to be accurate to within 10-15% of the quoted mineral percent with the exception of kaolinite. Samples containing 30-60% kaolinite may be in error by as much as 40% of the quoted mineral percent, although 20% is a more probable figure. Previous workers (e.g., Murray and Smith, 1958; Searle and Grimshaw, 1958; and Grim, 1962) have shown that mineralogy influences use in several ways: 1) through grain size, shape, and distribution in the rocks; 2) as a function of the chemical composition for components such as water, CO_2, Fe, and the alkalies; and 3) by the interrelated thermal reactivity of minerals. Properties such as fusion temperature, vitrification range, color of the fired product, bloatability, strength, and surface texture are all a function of the minerals present even though modified by other factors. The purpose of this report is not to evaluate all the possible mineralogical combinations which play a part in determining a specific use, but rather to present empirical correlations which are of practical value in determining use. As such, many of the correlations are exclusive rather than inclusive; that is, they yield criteria for excluding a particular rock for a particular use rather than criteria for attempting to explain all the interrelated factors which make a rock potentially useful. For some rock types the reliability of mineralogical correlations is limited by a small number of analyzed samples. At this stage of the shale-clay research project there are insufficient samples to delineate lateral or vertical mineral variations in any one unit; however, such research is planned for the future.

Mineral composition ranges and average values are plotted against use in Figure 8. The total number of samples for each potential use is listed in parenthesis. Uses for which there are insufficient data, such as

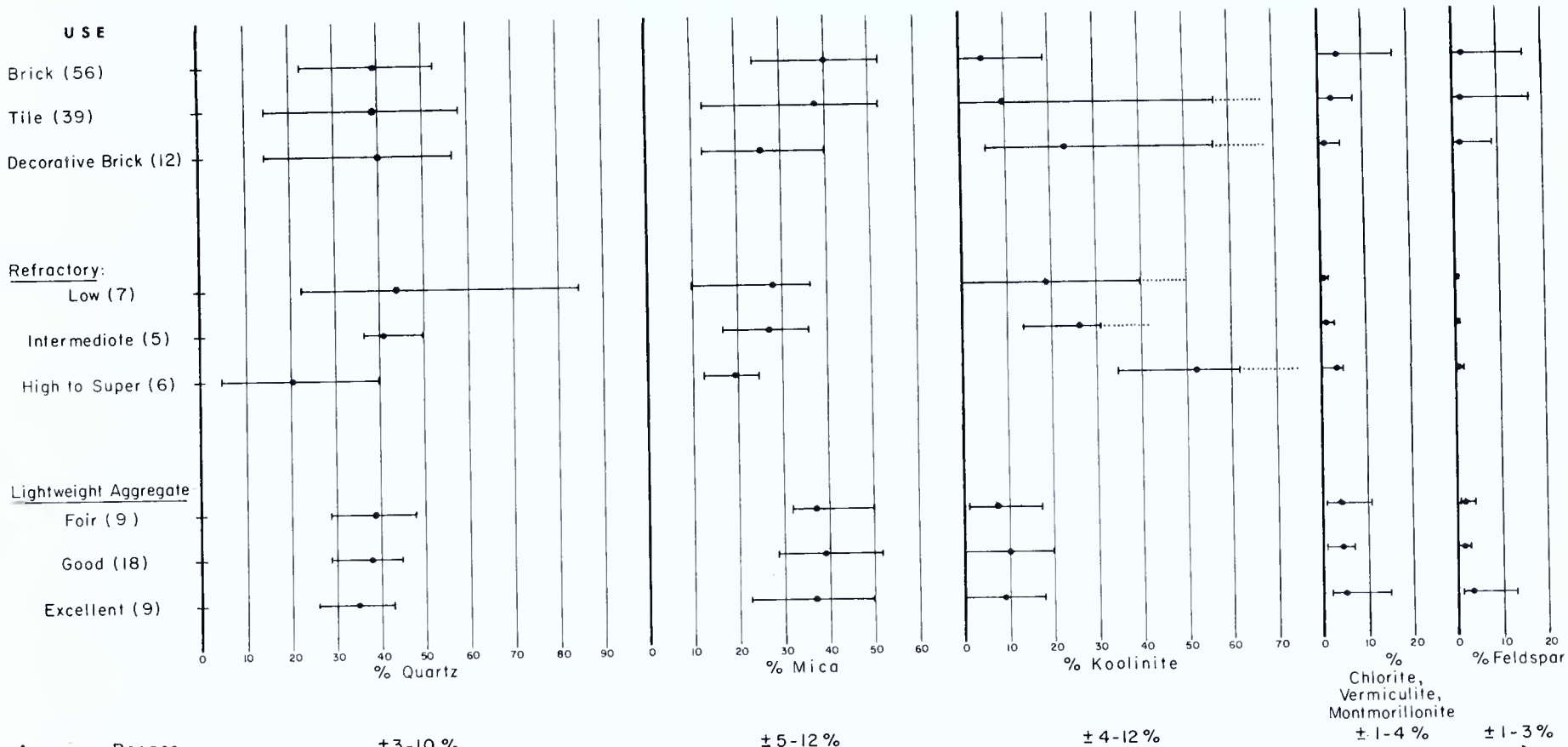


Figure 8. Mineral ranges and averages of clay materials for selected potential uses.

sewer pipe, filler, pigment, and sintered aggregate, are omitted. The category of "no use" is omitted because such samples encompass the complete mineralogical range. In general, the mineral range for a specific use is of more practical value than an average or a specific mineral percent. The first use group of brick, tiles (excluding chimney flue tile), and decorative brick exhibits a wide percentage range for all mineral components. Refractories, on the other hand, exhibit narrower ranges and lower percentage values for all minerals except kaolinite and generally show a consistent decrease or increase in both average mineral percent and range from low-duty to high-duty grades. Rotary-kiln lightweight aggregate is characterized by restricted mineral percentage ranges for nearly all mineral components. Detailed variation in mineralogy, which is probably the most useful single method for predetermining a potential use, is discussed below.

Brick.—Brick has a somewhat narrower range of quartz, mica, and kaolinite than the otherwise similar uses of tile and decorative brick. Typically quartz and mica tend to be present in a ratio of about 1:1. A minimum amount of about 20% quartz may prevent excess shrinkage, but the end points of this range are not clearly defined in the samples analyzed. At least 17% of chlorite-vermiculite-montmorillonite may be tolerated and may be beneficial in smaller amounts. Kaolinite does not exceed about 20% because it increases the refractoriness beyond the economical firing temperature of structural brick.

Tiles.—The mineralogical composition of the tile clays is similar to brick except that quartz, mica, and kaolinite have greater ranges (i.e. are less restrictive). Chlorite-vermiculite-montmorillonite (not differentiated from each other) are present in lesser amounts (to about 8% in the samples analyzed). Chimney flue tile (not included in the correlation) and drain tile may be mineralogically distinct from floor tile, but have not been analyzed separately.

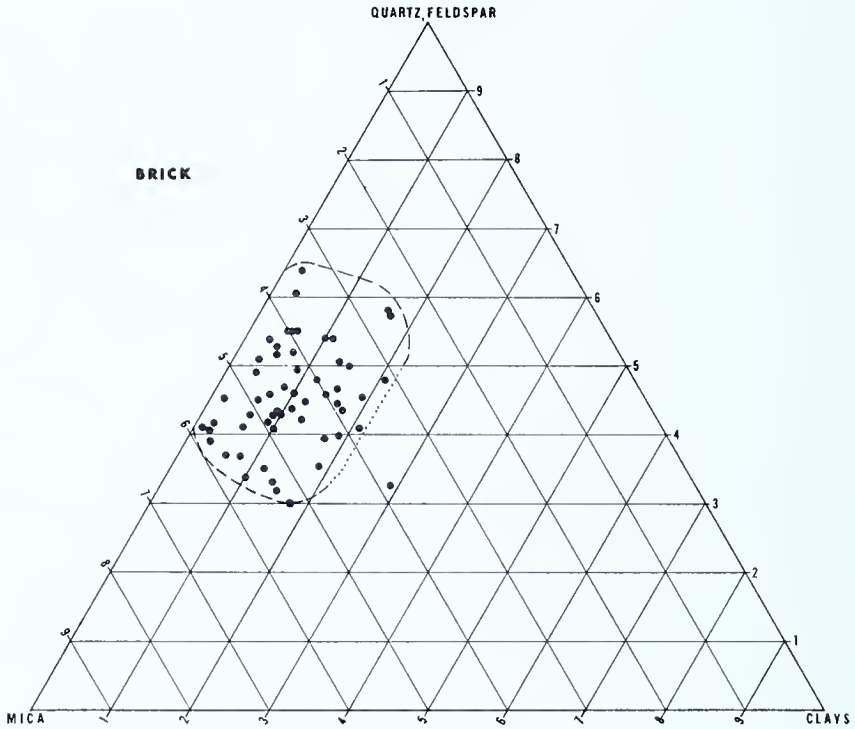
Decorative brick.—The quartz and kaolinite percentage ranges are similar to tiles whereas the mica, chlorite-vermiculite-montmorillonite, and feldspar percentages are similar to those for low temperature refractories. Because wide ranges of quartz and kaolinite are acceptable, these are not good index minerals. However, the mica content is restricted to less than 40%, the chlorite-vermiculite-montmorillonite to less than 6%, and the feldspar probably to less than 10%. Carbonate (not shown) also tends to be lower than for brick or tiles. At least a small amount of kaolinite appears to be necessary; in fact, the average kaolinite content increases from brick to tiles to decorative brick.

Refractories.—The various grades of refractories exhibit the best mineralogical correlations of all use categories studies. From low-duty to

super-duty refractories the average quartz content and mica content decrease, whereas the kaolinite content increases. Feldspar content is universally low. In the higher grade refractories which have a high kaolinite content (a minimum of about 40% ± 5% for the high- to super-duty grades) slightly more chlorite-vermiculite-montmorillonite is tolerated, but the amount is still less than in other use categories. One sample of nearly pure quartzite (about 85% quartz) tested as a potential low-duty refractory. From this maximum, quartz decreases to about 40% maximum quartz content for the high- and super-duty refractories. The narrow range limits of mica content, about 12% to 26%, for the higher grade refractories is probably significant especially at the upper end of the range where the limit is well defined by a large number of samples. However, part of the narrow ranges of these refractory minerals may have resulted from the small number of samples examined. A decreasing amount of carbonate (not illustrated) from low- to high-duty refractories also is characteristic.

Lightweight aggregate.—All analyzed minerals are present within very narrow limits with the exception of chlorite-vermiculite-montmorillonite and possibly carbonate minerals. This is the most important distinguishing characteristic of all grades of rotary-kiln lightweight aggregate. Quartz content, which ranges from about 26% to 49%, tends to decrease slightly toward the more expandable material. Average mica percentages show the same trend, but the ranges for the three grades overlap. Kaolinite does not exceed 20%. Clay mineral percentages are lower than for all other use categories and the upper limits are well bracketed, especially for shales (Table 11). A small amount of chlorite-vermiculite-montmorillonite (much of which is probably vermiculite) appears to be beneficial since all samples contained at least 1%; however, the upper limit is variable. Most of the samples contain a significant amount of carbonate minerals which suggests that at least a small amount is necessary to yield volatile CO_2 for bloating. However, it should not exceed that amount which would lower the fusion temperature or rate to the point where bloating is inhibited.

Another plot illustrating mineralogical variation among the various use categories is presented in Figures 9 through 12 and in the summary diagram of Figure 12. The apices of these triangular diagrams are quartz-feldspar, mica (or illite), and clay minerals which include kaolinite, and chlorite-vermiculite-montmorillonite. Although feldspar behaves as a strong flux relative to quartz, this difference in behavior does not significantly alter the plots because of the small amount of feldspar present in the samples examined. For the purpose of plotting, these mineral components were recalculated from an X-ray analytical average of 91%, for the five components, to 100%. These individual



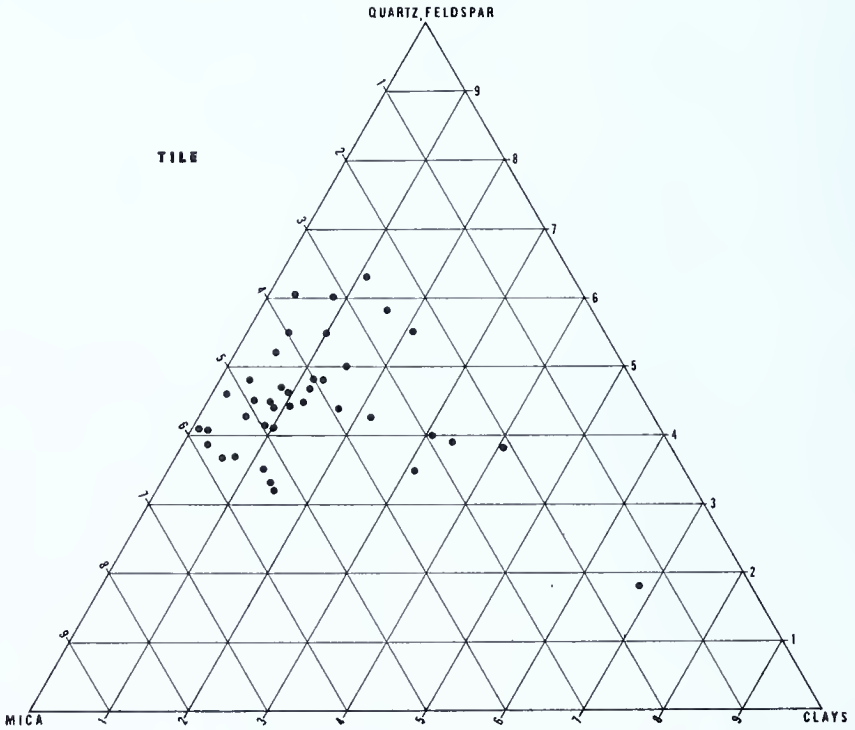
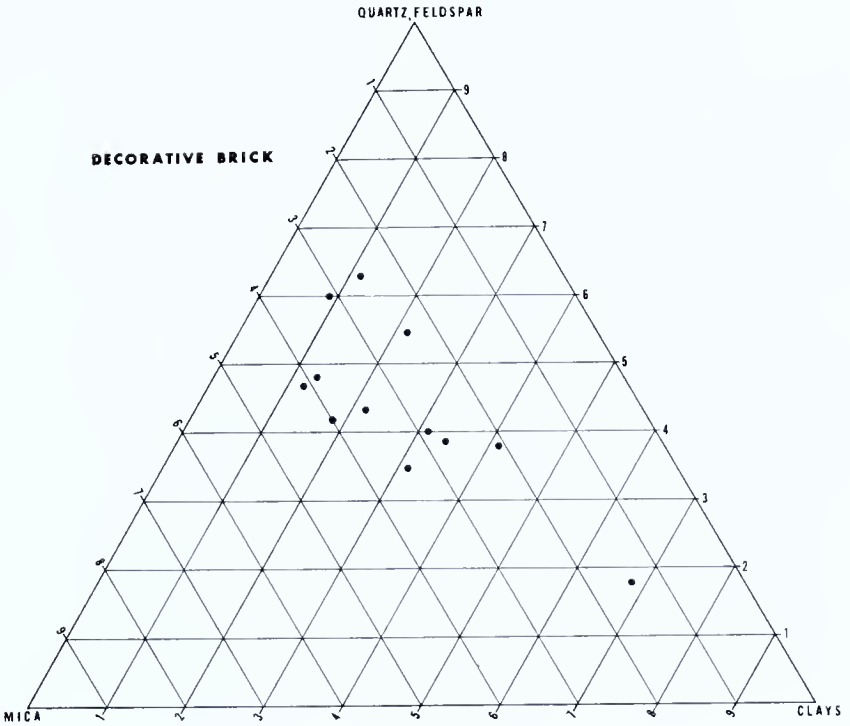


Figure 9. Mineral composition fields for brick and tile.



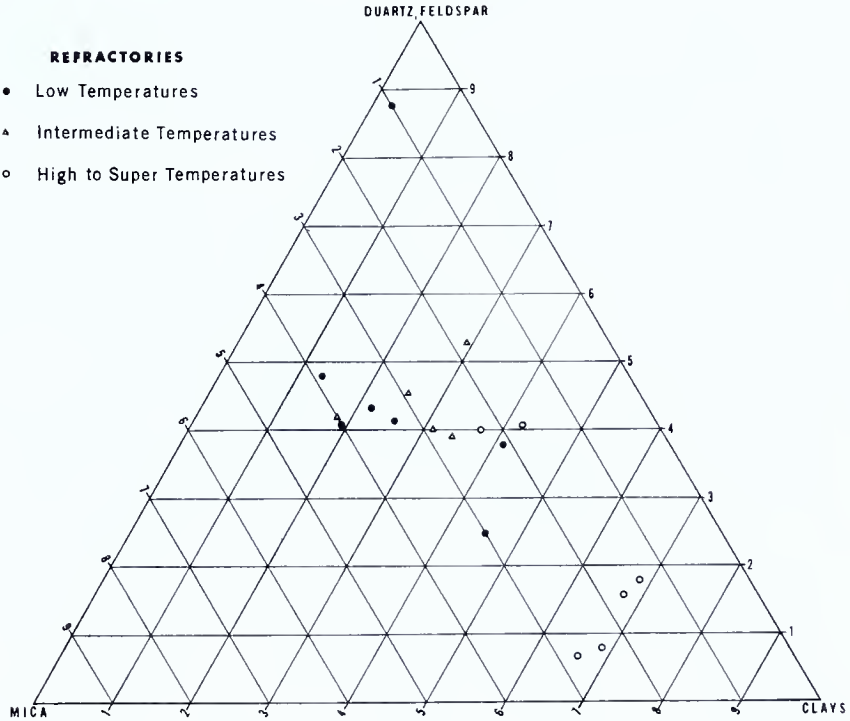


Figure 10. Mineral composition fields for decorative brick and refractories..

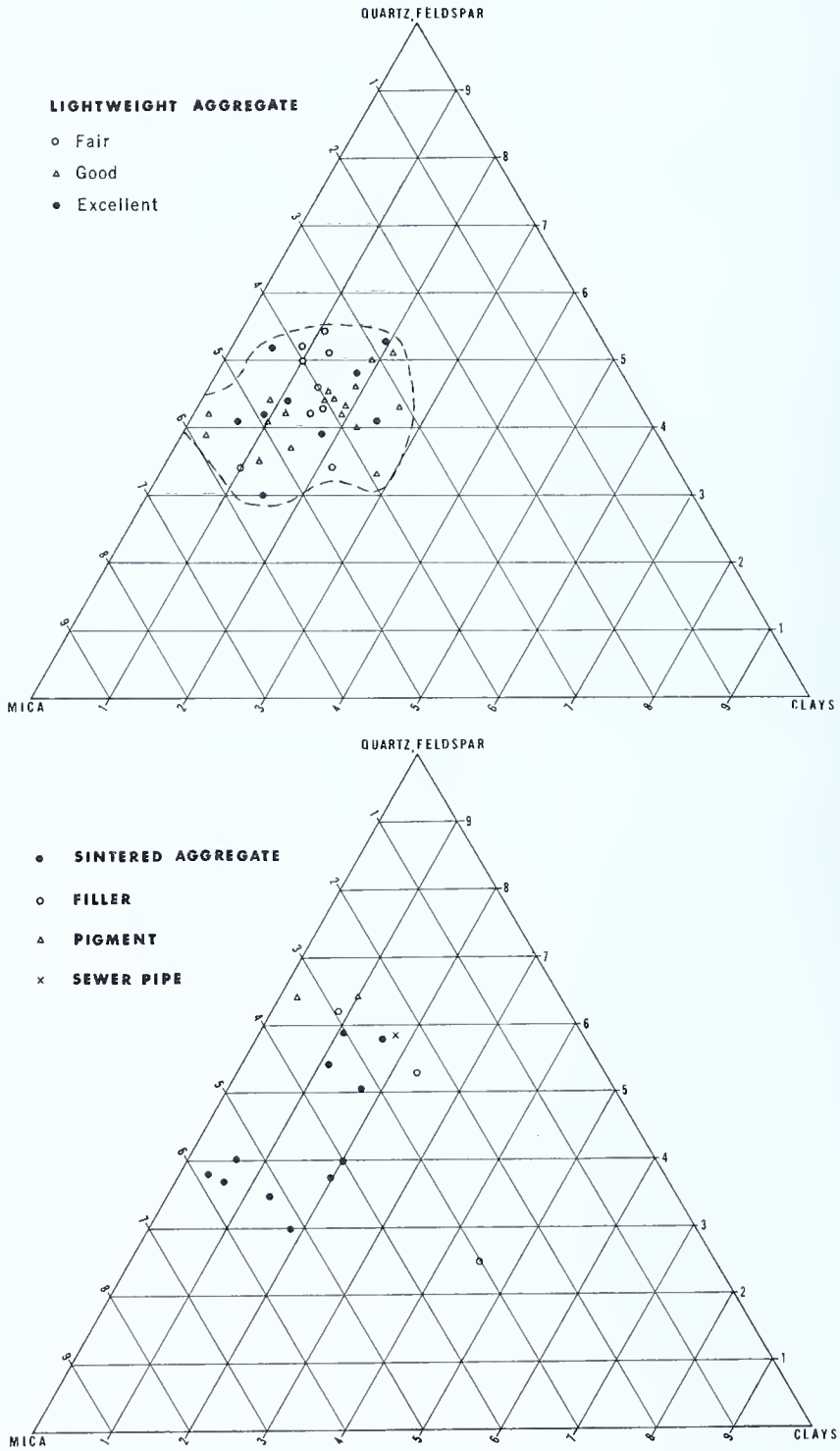


Figure 11. Mineral composition fields for lightweight aggregate and for sintered aggregate, filler, pigment, and sewer pipe.

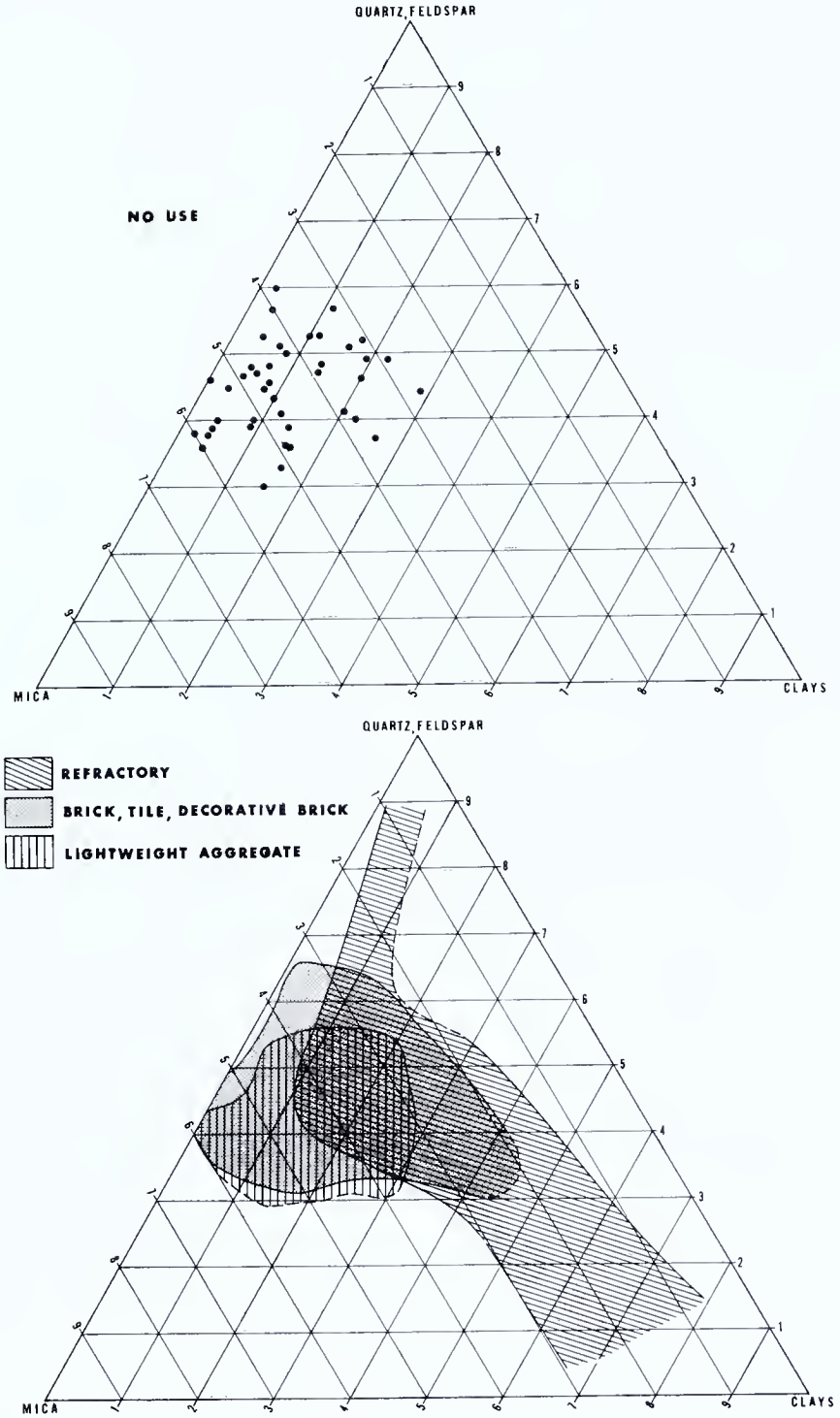


Figure 12. Mineral composition fields for samples showing no use and a summary comparison for major use categories.

plots show the density distribution for all samples for a specific use. On the other hand the summary diagram (Fig. 12) illustrates the major differences in mineralogical composition among the three major groups, 1) brick and tiles (excluding chimney flue tile which is similar to low-duty refractories) which are largely structural clay products, 2) refractories, and 3) rotary-kiln lightweight aggregate. Those samples containing significant carbonate minerals (greater than about 5%) did not exhibit any consistent distribution within the mineralogical field for each use and hence are not shown in the diagrams. In general these diagrams illustrate that there is a mineralogical field of overlap where any one sample has the correct mineralogical composition for possible use in any of the three major use categories, but also illustrates that significant differences do exist. Significant sample concentrations within each field are not apparent.

Brick.—Brick (Fig. 9) shows a rather narrow field nearly along the quartz, feldspar-mica join, reflecting a low clay mineral content. The quartz and feldspar to mica ratio is approximately 1:1. Sample point distribution is a maximum near the center of the field at approximately 10% clay minerals, 45% mica and 45% quartz and feldspar. Although these percentages are somewhat high because other minerals (notably carbonate) are often present, they suggest an approach to optimum mineral composition.

Tiles.—Structural tiles (Fig. 9) are very similar to brick except that the field extends further toward the clay minerals apex. The distribution of points is approximately the same as for brick.

Decorative brick.—The mineralogical field is near the center of the triangular diagram (Fig. 10), trending more toward the clay apex than either brick or tiles, but the number of samples is insufficient to draw meaningful conclusions. As noted previously, the mineralogical composition is similar to the lower temperature refractories.

Refractories.—All grades exhibit a low and relatively constant mica content (Fig. 10). The grades vary almost linearly with the total clay mineral content, increasing in fusion temperature toward the clay apex. The open circles near the center of the diagram are largely high-duty refractories, whereas the open circles nearer the clay apex are super-duty refractories. Although the total number of samples is small, the correlation is excellent and probably valid (also see Table 11).

Lightweight aggregate.—The rotary-kiln lightweight-aggregate field (Fig. 11) is relatively small and extends somewhat closer to the mica-clay join than the other use fields. The platy habit of mica may be an influ-

ential factor in expandability. The distribution of points exhibits a weak concentration at about 43% quartz and 40% mica but shows no apparent relation to quality.

Too few sintered aggregate, filler, sewer pipe, and pigment samples were examined to draw any conclusions (Fig. 11). However, there is a conspicuous lack of points in the area of maximum point concentration for brick, tiles, and rotary-kiln lightweight aggregate which results, in part, from the fact that tests for sintered aggregate were made on material which was not suitable for these other uses.

The plot of samples with no use (excluding sintered aggregate, pigment, filler, and sewer pipe) falls in the field of major concentration for brick, tiles, and to a lesser extent for rotary-kiln lightweight aggregate (Fig. 12). Approximately half of these samples contain significant amounts of carbonate minerals, a proportion much greater than for samples in the use categories (Table 12). Most of these samples can be eliminated on the basis of total Fe content (Fig. 17), rock type (Fig. 13), or pH (Fig. 20).

The summary diagram for three major use categories (Figure 12) illustrates the mineralogical fields summarized from the individual diagrams. The shift in the fields is approximately toward the clay-mineral apex from brick to high-duty refractories. With the exception of high- and super-duty refractories there is an area of overlap which, compared with the average shale tested, is as follows:

	Overlap of Mineral % Fields	*Percent in Average shale*
Feldspar, Quartz	38 – 55	40
Mica	30–45	40
Clays	10 – 25	10
Other	0 – 10	approx. 10

From this comparison it can be seen that many shales will fall within the region of multiple use, but that the average shale is low in quartz, feldspar and high in mica, and somewhat low in clay-mineral content.

Although no quantitative measurements were made for carbonate mineral content, samples which contained more than 5% were noted. The percent of samples which contained this amount are tabulated with their specific use in Table 12. Nearly 40% of the brick and tile samples but only 17% of the decorative-brick samples contained significant carbonate. As with other correlations, decorative brick is similar to refractory products which decrease in carbonate content from 29% of the samples for low-duty refractories to 0% for the six high-duty and super-duty refractories. This is a reflection of the lack of carbonates in most

of the flint clays sampled, but also can be considered to restrict the utility. Rotary-kiln lightweight-aggregate samples more frequently contain significant carbonate than samples of the other use categories, reinforcing the previous suggestion that at least a moderate amount of carbonate is desirable. However, carbonate is less frequently present in the better quality lightweight aggregate (see Chemical Correlations).

Another distinction among the use categories (not illustrated) is the kaolinite to chlorite-vermiculite-montmorillonite ratio. Whereas brick and tiles tolerate a large amount of chlorite-vermiculite-montmorillonite, decorative brick will not, and the ratio in decorative brick is correspondingly much greater and similar to the refractory grades. There is also a low ratio in rotary-kiln lightweight aggregate which is a reflection of low kaolinite content.

Several other types of plots (not illustrated) exhibited weak correlations which might become important in a more detailed study. The clay/mica ratio tends to increase in the following sequence: No use—brick—tiles—decorative brick—refractories. The position of lightweight aggregate in this sequence is uncertain. This sequence can also be observed from the summary diagram of Figure 12. Illite line broadening (mica degradation) tends to increase from brick, tiles, decorative brick, and no use samples to rotary-kiln lightweight aggregate to a maximum for the higher grade refractories. This is similar to the correlation between mica degradation and rock type (Fig. 14), and arises

Table 12.—*Percent of samples containing carbonate, according to use*

	% Samples with carbonate
Brick (56)	40
Tile (36)	35
Decorative Brick (12)	17
Low-Duty Refractory (7)	29
Intermediate-Duty Refractory (5)	20
High-Super-Duty Refractory (6)	0
Fair Lightweight Aggregate (9)	78
Good Lightweight Aggregate (18)	67
Excellent Lightweight Aggregate (9)	56
No Use (46)	51

from a correlation between rock type and use. With the exception of well-crystallized micas from the Precambrian and lower Paleozoic units of the Piedmont (small angular line broadening and hence very little degradation), there is no apparent correlation between age of formation and mica line broadening. The mineralogical variation of the analyzed Martinsburg shales and siltstones shows no consistent geographical dis-

tribution pattern. However, more detailed sampling might very well bring out differences not evident in this preliminary sampling.

In summary, the mineralogical composition of clay-shale samples is a major controlling factor in determining potential use. The influence and importance of the most commonly occurring minerals is as follows:

Quartz.—Although rather wide ranges are tolerated for most uses, quartz content is quite restrictive for clay refractories, decreasing as the refractory grade increases. The tolerated range in rotary-kiln lightweight aggregate is narrow; also, the amount present may decrease as expandability increases. Many shale samples fall outside the quartz range for lightweight aggregate and probably can be eliminated from consideration as potential rotary-kiln lightweight aggregate. A minimal amount of quartz appears to be required to make brick, especially when compared to the wider range of quartz in tiles and decorative brick. However, the quartz limits are not well bracketed by samples with amounts outside the ranges (Table 11). In general, quartz reduces plasticity, shrinkage, tensile strength, and expandability (Searle and Grimshaw, 1958; Grim, 1962). Because for any one product one of these factors may be desirable and another undesirable, there will be a compromise range of quartz content which is optimum; e.g., in certain bricks where strength is desired but shrinkage should be minimal.

Mica (illite).—Relatively wide ranges are tolerated for all uses except high- and super-duty refractories. Decorative brick and refractories should contain less than 40%, whereas rotary-kiln lightweight aggregate generally contains 30% to 50% mica. In other use categories mica does not appear to be a good indicator mineral for potential use. During firing mica probably contributes potassium which acts as an alkali flux. The platy habit and grain size of mica contributes to the reactivity and expansion characteristics of rotary-kiln lightweight aggregate, especially where the flakes are oriented as in slate and phyllite or schist.

Kaolinite.—Kaolinite is a good indicator mineral with respect to use. High percentages are beneficial or required for decorative brick and refractories, the average content of the samples analyzed increasing linearly with the refractory grade. Low percentages and a relatively narrow range are characteristic of rotary-kiln lightweight aggregate. Kaolinite is one of the few minerals which differentiates brick from tiles (excluding chimney flue tile), the former having a maximum of about 18%, and the later about 60%. However, there is considerable overlap and many samples are potentially useful for both. These correlations of kaolinite with the higher temperature products are a reflection of its relatively high fusion temperature, and high temperature recrystallization products. High percentage kaolinite samples also tend

to produce the light-colored, low-iron fired products which are often most desirable for decorative brick and clay refractories.

Chlorite-Vermiculite-Montmorillonite.—This group of related minerals has a significant influence on use because of behavior during firing. Vermiculite expands to several times its original volume and as a result is beneficial for expandable lightweight aggregate at least in moderate amounts (5%-15%). Alkalies may also be present through base exchange reactions or adsorption, and these may aid in fluxing action. This is especially true of montmorillonite which, however, was not present to any significant amount in the samples analyzed. In addition, their platy habit may influence reactivity and expansion. Because of these characteristics, these minerals, or a similar flux, are probably essential to rotary-kiln lightweight aggregate, prohibitive for most decorative brick and refractories (except in amounts less than 5%), and tolerated in most brick and tiles.

Feldspar.—Because the quantity of feldspar in the samples studied was small, the data do not support definite conclusions. However, refractory samples analyzed are feldspar deficient, usually containing less than 3%. Rotary-kiln lightweight aggregate apparently benefits from feldspar in the range of 2% to 12%. Feldspar, as a source of alkalies, acts as a flux, promoting vitrification. If volatiles are present, the glass resulting from the feldspar may aid in sealing or enclosing these volatiles and thus enhancing its expansion for use as a lightweight aggregate (Murray and Smith, 1958). The low fusion temperature of feldspar-rich rocks is responsible for its limited range in high-temperature refractories.

Carbonates.—Although quantitative measurements of carbonate minerals were not made in this study, an analysis of samples containing significant amounts indicate that it is detrimental to decorative brick and refractories in amounts greater than 5%-10%, but is beneficial to rotary-kiln lightweight aggregate up to some as yet undetermined upper limit. Carbonate minerals act as a flux. They also release volatiles which can result in vesiculation and release calcium which may form silicates or undesirable efflorescent products by combination with sulfates or phosphates. (See also Chemical Correlations.)

Rock-Type Correlations

Graphs illustrating two kinds of rock-type correlation are presented in Figures 13 and 14, one of which is a practical correlation with use (Fig. 13) and the other a more fundamental correlation relating the origin of a particular rock type to the degree of mica crystallinity (Fig. 14). From past experience particular rock types are known to be suitable for

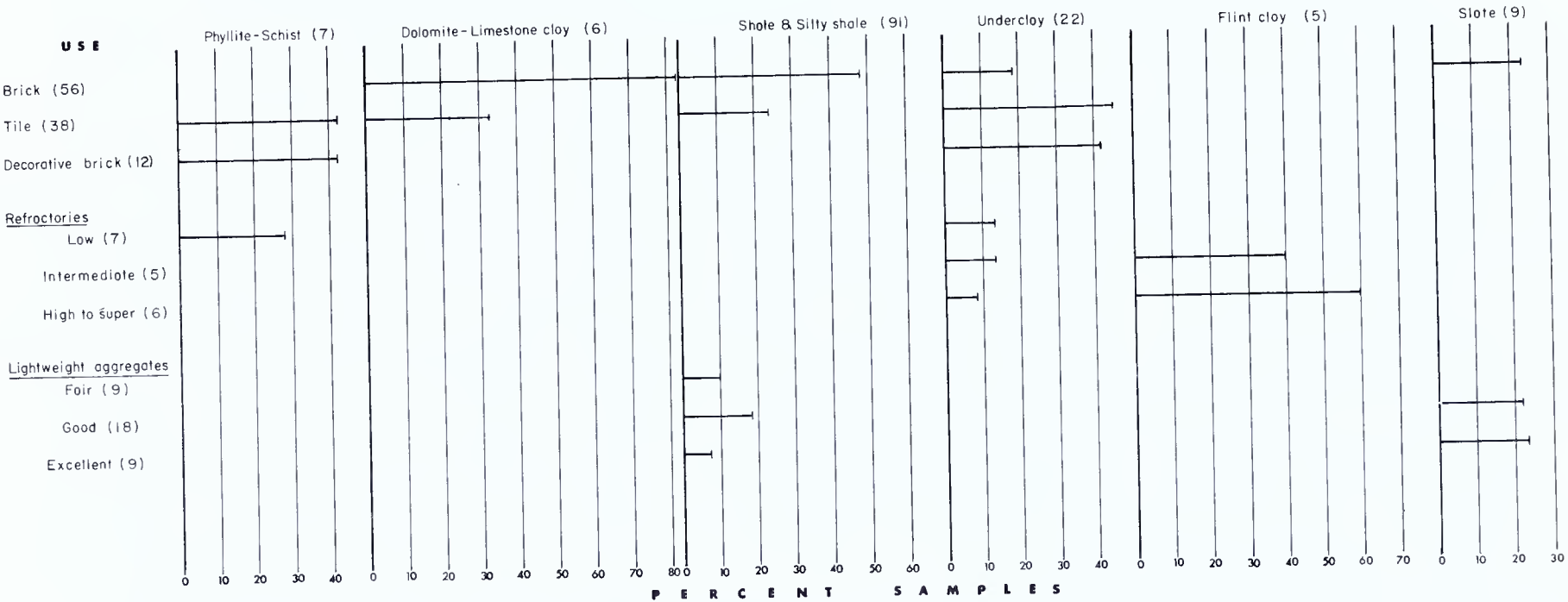


Figure 13. The percent samples of a specific rock type with a specific potential use.

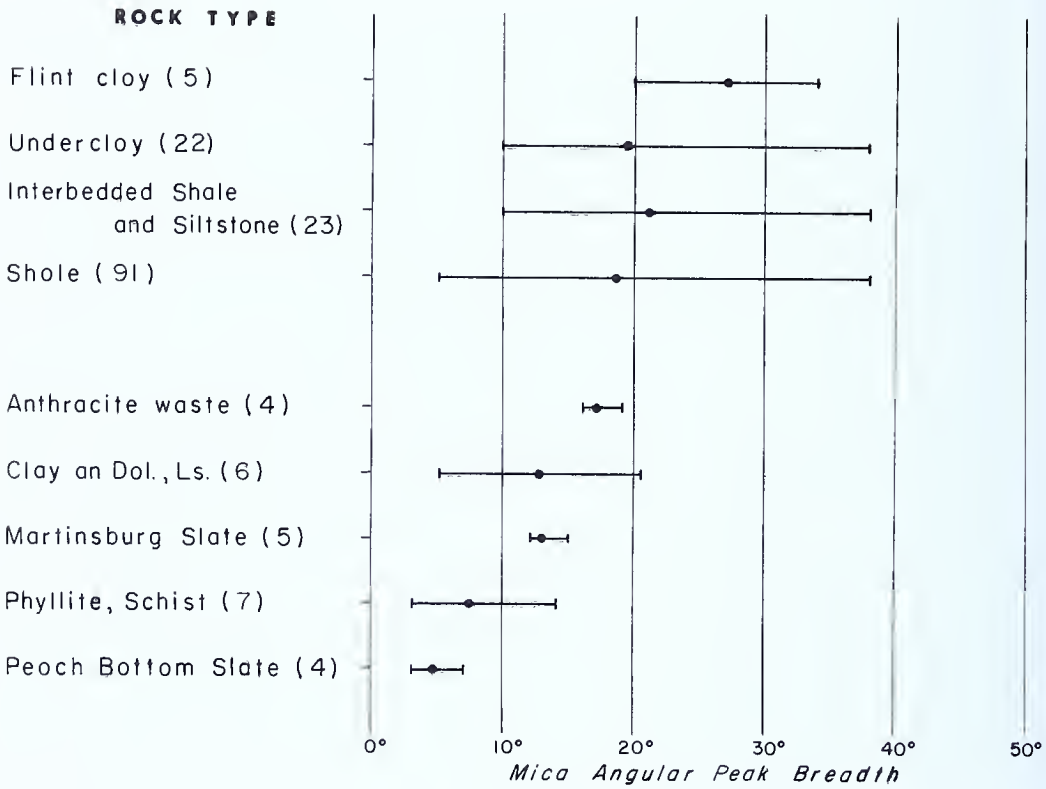


Figure 14. Illitic mica degradation (angular (001) X-ray peak breadth) related to rock type.

specific uses. For example, many shales are usable for brick and tile, others only for expanded rotary-kiln lightweight aggregate. Underlays and flint clays are used for various grades of refractory brick. However, there are few quantitative measurements which will yield the extent to which a particular rock type can be expected to have a specific use. Furthermore, data on rock types such as slate and phyllite are scanty. The purpose of this correlation discussion is to evaluate a wide range of rock types as potential sources for a specific use.

In Figure 13 data for shales and interbedded shales and siltstones have been compiled together (a separate plot of shales and silty shales revealed the same use pattern). The number of samples of a particular rock and of a specific use are given in parentheses. The smaller this number, the less reliable is the correlation. The abscissa presents the percent of usable samples from the total analyzed for that particular rock type. Thus for example, of the 91 shales analyzed about 48%, or 43 samples, were suitable for brick.

The correlations illustrated in Figure 13 can be summarized as follows:

Brick.—Of all the use categories, brick is least restrictive with respect to rock type. A large percentage of clays associated with limestone or

dolomite (based on only 6 samples) and of shales make good brick, 83% and 48% respectively. Underclay and slate are usable, but less frequently. These analyses indicate that flint clay and phyllite or schist (including their residual clays) do not make good brick.

Tiles.—Materials suitable for tile are similar to those suitable for brick except that slate is not good for tile. In addition, 40 percent of the samples in the phyllite-schist category are usable for tile; all usable samples are of residual material weathered from phyllite and schist and not of the rock itself. More underclay samples can be used for tile than for bricks; conversely, more shale samples can be used for brick than for tile.

Decorative brick.—Use is restricted to phyllite-schists which have weathered to residual kaolinite-rich clays, and to underclays. As with other correlations, decorative brick is similar to low-grade refractories. Note that no shales and no clays associated with limestone or dolomite were found to be usable for decorative brick. Either a high percentage of the samples of a particular rock type can be used, or none at all. This is also the case with all grades of refractory products.

Refractories.—Low-duty refractories can be made from residual kaolin clays associated with phyllite-schist and from underclays, whereas the intermediate-, high-, and super-duty refractory sources are underclays and flint clays. Of the underclays tested, 35 percent could be used for some grade of refractory whereas 100 percent of the flint clays tested are potential sources in the intermediate- to super-duty refractory categories. Not illustrated in Figure 13 are one quartzite sample (about 85% quartz) which tested as a potential low-grade silica refractory and one residual clay associated with sandstone which is a potential high-duty refractory.

Lightweight aggregate.—Less than half of the shales and slates tested in the rotary kiln are potential sources. A comparison of the two rock types suggests that slate, especially the Martinsburg slate, may be a better potential source of excellent-grade lightweight aggregate than shale, but more samples should be tested before such a statement can be considered valid.

Except for the metamorphic rocks, slate and schist-phyllite, the exclusion of rock types from a specific use category can be explained primarily on the basis of mineral content and certain specific chemical elements, and secondarily by physical properties such as pH and water of plasticity (succeeding discussions). In the case of the metamorphic rocks, grain size and rock texture can be expected to be significant controlling factors. The homogeneity and excellent cleavage of slate prob-

ably enhance its value as a source of expandable rotary-kiln lightweight aggregate. The large grain size and presence of interlocking grains in schist may inhibit the low fusion temperature necessary to yield brick. In general there is an excellent correlation between rock type and specific use.

An interesting correlation between rock type and the extent of degradation of muscovite (illite) (Fig. 14) may yield fundamental data on the origin of certain rocks. The mica measurement used is the breadth of the first basal spacing taken from X-ray diffractometer traces, and measured in degrees (Lapham and Jaron, 1964). From theoretical considerations, this breadth should increase with the extent of alteration, or breaking down, of the mica; that is, increasing illitic character as opposed to well-crystallized muscovite. It may also relate to mica grain size because increasing alteration during weathering or transport tends to decrease grain size. Thus the measurement of this parameter is a potential tool for measuring the degradation to which a mica has been subjected. However, both duration of the alteration processes and the original degree of crystallization of the mica must be considered. The graph in Figure 14 supports the usefulness of such a measurement. Well-crystallized muscovite in metamorphic rocks exhibits a low angular breadth and a narrow range of values. The average angular breadth of the mica (001) is a maximum in flint clay, suggesting that these clays have been, at least in part, extensively reworked or transported with respect to their original source rocks. Further work along this line may prove useful in determining the character of source areas of sediments and the extent of transportation or reworking previous to lithification.

Chemical Correlations

General Statement.—The relationship between the chemical composition of a clay or shale source material and manufactured clay products is not clearly understood. However, it is apparent, upon correlating, that those use categories whose application is of a determinate nature correlate best.

CO_2 (Fig. 15).—The principle sources of carbon dioxide (CO_2) in a clay material are carbonate minerals such as calcite, dolomite, and siderite, and organic matter.

Brick and tile will tolerate relatively large amounts of CO_2 from mineral carbonates, especially if the grains are small and evenly distributed. The average percent CO_2 for each refractory grade and decorative brick is low, less than 1.5%, and the upper range limit is well defined at about 2%. As a contrast, moderate amounts of CO_2 appear to be beneficial to both rotary-kiln lightweight aggregate and

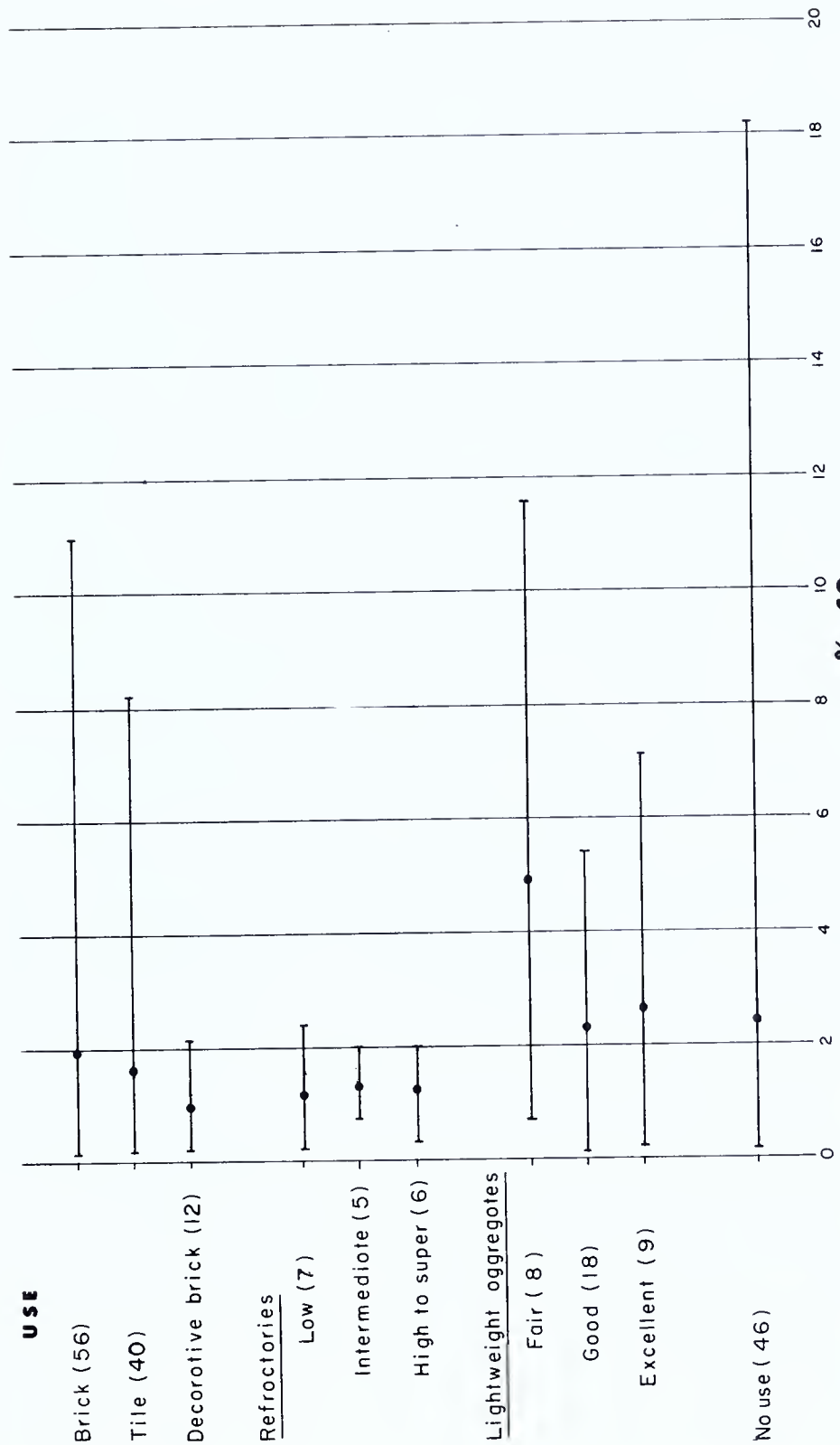


Figure 15. Weight percent CO_2 versus potential use.

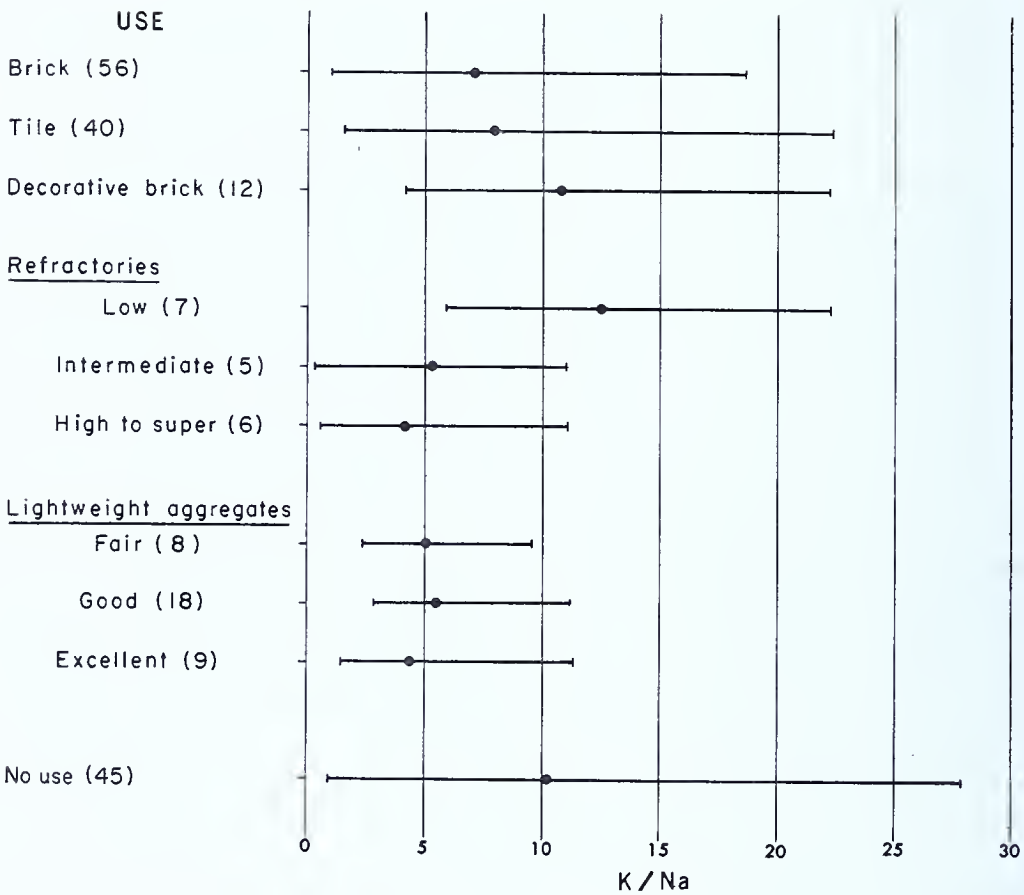


Figure 16. The alkali ratio of K/Na versus potential use.

sintered aggregate. (See Mineralogical Correlations, Table 12.) The No Use category ranges from approximately 0.2 to 18%, exceeding the range of all potential-use categories. Usable samples have a maximum permissable CO_2 content of about 12%.

The average percent CO_2 for underclays suitable for decorative brick is 1.20 and for fire-clay refractories is 1.57; however, there are some underclays which cannot be used in either category. These underclays have a noticeably higher average percent CO_2 of 1.83. CO_2 content therefore seems to be a restrictive factor in determining whether a clay can be used for decorative brick and refractories.

CO_2 dissociates from carbonates at about 800° C., and is largely responsible for the voids in a clay product. A vesicular appearance limits the use of a fired clay for decorative brick, but is absolutely necessary for the production of lightweight aggregate. The presence of CO_2 in relatively large amounts indicates an abundance of organic carbonaceous material and/or an oxide flux of calcium, magnesium, or iron. Carbonaceous material may provide a reducing environment during rapid kiln

firing, which beneficiates certain vitrification-type chemical reactions. Oxide fluxes lower the melting point and shorten the vitrification range of a clay product.

K/Na Ratio (Fig. 16).—The potassium-sodium ratio (K/Na) is derived largely from mica and feldspar in a clay material. This type of a ratio seems to have its greatest use in distinguishing low-duty refractories from higher refractory grades.

The K/Na ratio for brick and tile is unrestrictive. Decorative brick has a moderately high average K/Na ratio of 10.7; the lower range limit (4.2) may be restrictive. Low-duty refractories range from 5.9 to 22.3, and average 12.5. Underclays potentially useful as low-duty refractories range from 7.9 to 10.7 and average 9.7. Intermediate- and high-super-duty refractories range from about 0.5 to about 11.0, intermediate-duty refractories averaging 5.3 and high-super-duty refractories 4.2. The average K/Na ratio decreases irregularly with increasing refractory grade. Fair and good rotary-kiln lightweight aggregate have a slightly higher K/Na ratio than excellent rotary-kiln lightweight aggregate. The 4.4 average K/Na ratio for excellent lightweight aggregate is lower than that for all listed use categories except high-super-duty refractory brick which has an average K/Na ratio of 4.2.

The No Use samples range from about 0.9 to about 27.9. Twenty-five of the forty-six No Use samples are shales. They range from 0.9 to 20.1 and have an average K/Na ratio of 8.3. Only one of these samples falls below 3.3. The sixty-five other shales, which are usable, range from 1.2 to 25.7 and average 6.6. Twelve of these usable shales (ca. 18%) have a K/Na ratio of less than 3.3. This seems to indicate that shales having a K/Na ratio of less than 3.3 may fall into one of the several use categories listed. For example, approximately 16% of those samples potentially useful as rotary-kiln lightweight aggregate have a K/Na ratio of less than 3.3.

Total Fe (Fig. 17).—Both the range and average percent iron (Fe), recalculated from ferric and ferrous oxide, for tile are unrestrictive. Iron in even small amounts tends to be detrimental to decorative brick and refractories. Decorative brick is restrictive, ranging from 1.0 to 2.2, and averaging 1.4% total Fe. The upper limit of brick is unrestrictive; however, the lower limit (ca. 1.5%) approximates the average percent total Fe for decorative brick, and may be restrictive. Many samples potentially useful for brick might also be useful for decorative brick if their Fe content were lower. The average percent total Fe for each refractory grade is quite low, less than 1.2%, and the upper limit is about 2.3%. In contrast, moderate amounts of Fe seem to be necessary for those materials suitable for rotary-kiln lightweight aggregate. Iron

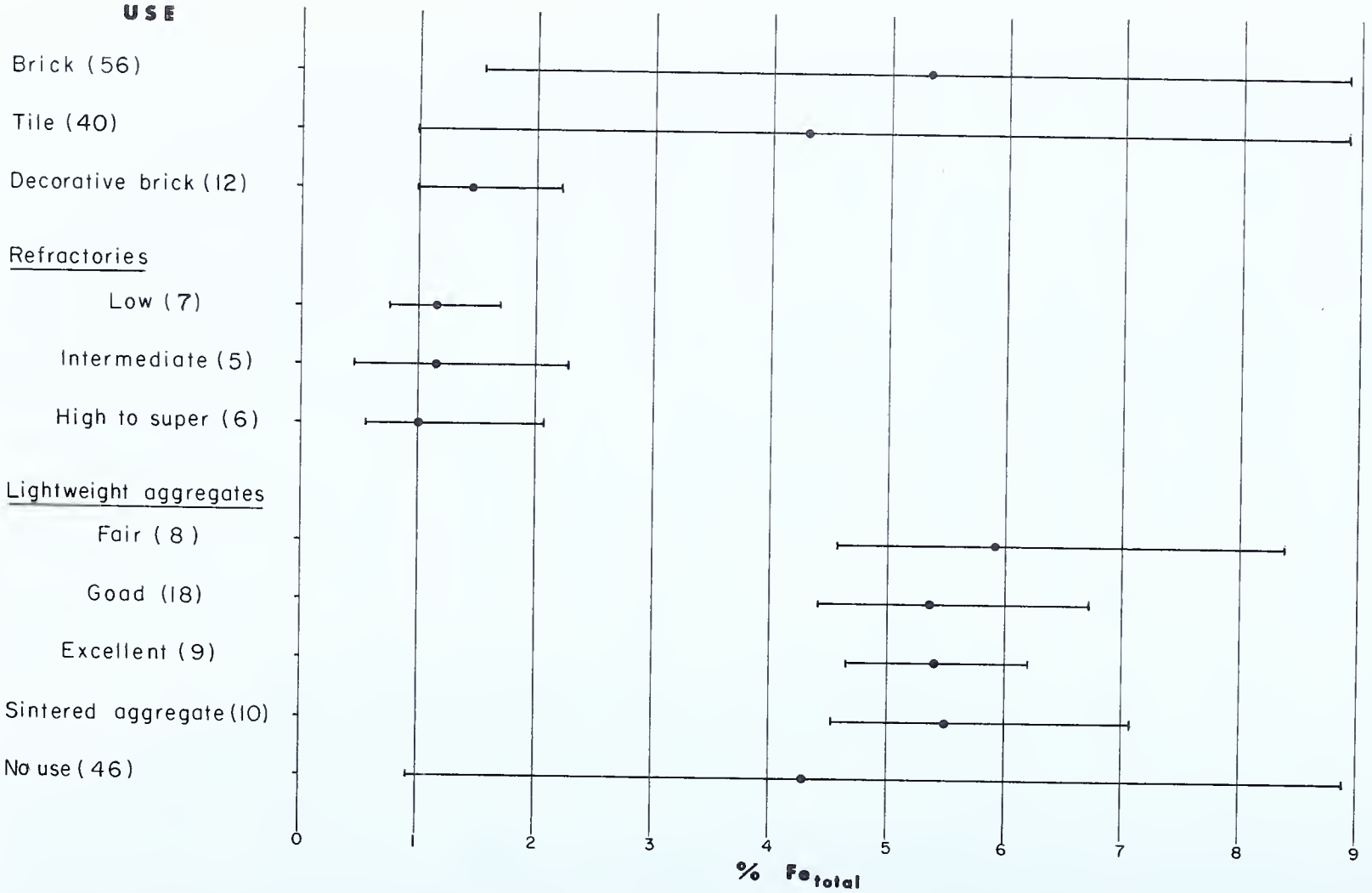


Figure 17. Total percent Fe versus potential use.

oxide combines with silica at comparatively low temperature, fluxing and decreasing the refractoriness of a clay product. In a reducing atmosphere ferric oxide releases oxygen which is thought to be a significant chemical reaction in the bloating of shales and clays (Wilson, 1963, p. 11). Rotary-kiln lightweight aggregate and sintered aggregate require a minimum of about 4.4% total Fe, and do not exceed 7% in the good and excellent categories. The average for all lightweight aggregate is about 5.5%. The No Use category ranges from 0.9 to 8.9% total Fe, encompassing the complete range of potential uses.

Iron compounds are one of the major contributors to the final color of a fired clay product. Fired samples suitable for decorative brick display a broad range of eye-pleasing buffs, yellows, pinks, and grays. Most common iron compounds found in clays will dissociate at temperatures below 500° C. If an oxidizing atmosphere is present ferric oxide will form. Color, tone, and shade of the fired product will depend upon the amount of this ferric oxide present, and its distribution through the clay product (Searle and Grimshaw, 1958, p. 663). Although it is virtually impossible to predict the color of a burned clay, clays low in iron will not burn red; hence, the restrictive nature of iron for decorative brick.

Fe^3/Fe^2 Ratio (Fig. 18).—The oxidation state of a clay material may be approximated by the ratio of ferric iron to ferrous iron (Fe^3/Fe^2); this ratio also serves as a rough indication of the amount of weathering undergone by a clay material.

Brick and tile have the broadest range and highest average Fe^3/Fe^2 ratio of any use category analyzed, illustrating that the Fe^3/Fe^2 ratio of these categories is not a critical factor. Decorative brick and low-duty refractories have low average Fe^3/Fe^2 ratios; but decorative brick has a broader range. Compared to low-duty refractories, intermediate- and high-super-duty refractories have somewhat narrower ranges and a lower Fe^3/Fe^2 ratio.

The No Use category ranges from about 0.4 to about 15.6, and averages about 3.5. The twenty-five shales which fall into the No Use category range in Fe^3/Fe^2 from 0.4 to 8.5, and average 3.5. The sixty-five other shales which are usable range from 0.1 to 36.0, and have an average Fe^3/Fe^2 ratio of 3.8. However, the most "useful" shales are not necessarily those which show a high degree of weathering. The Fe^3/Fe^2 range of "useful" shales is broad because of the wide tolerances in brick and tile categories, and those shales which are eliminated from any use category, are eliminated because of factors other than their Fe^3/Fe^2 ratio. Hamlin (personal communication) noted that a clay material may be upgraded within a particular use category, i.e. from a low-duty to an intermediate-duty refractory, if it is less weathered. Many more samples should be tested, however, to further corroborate this relationship.

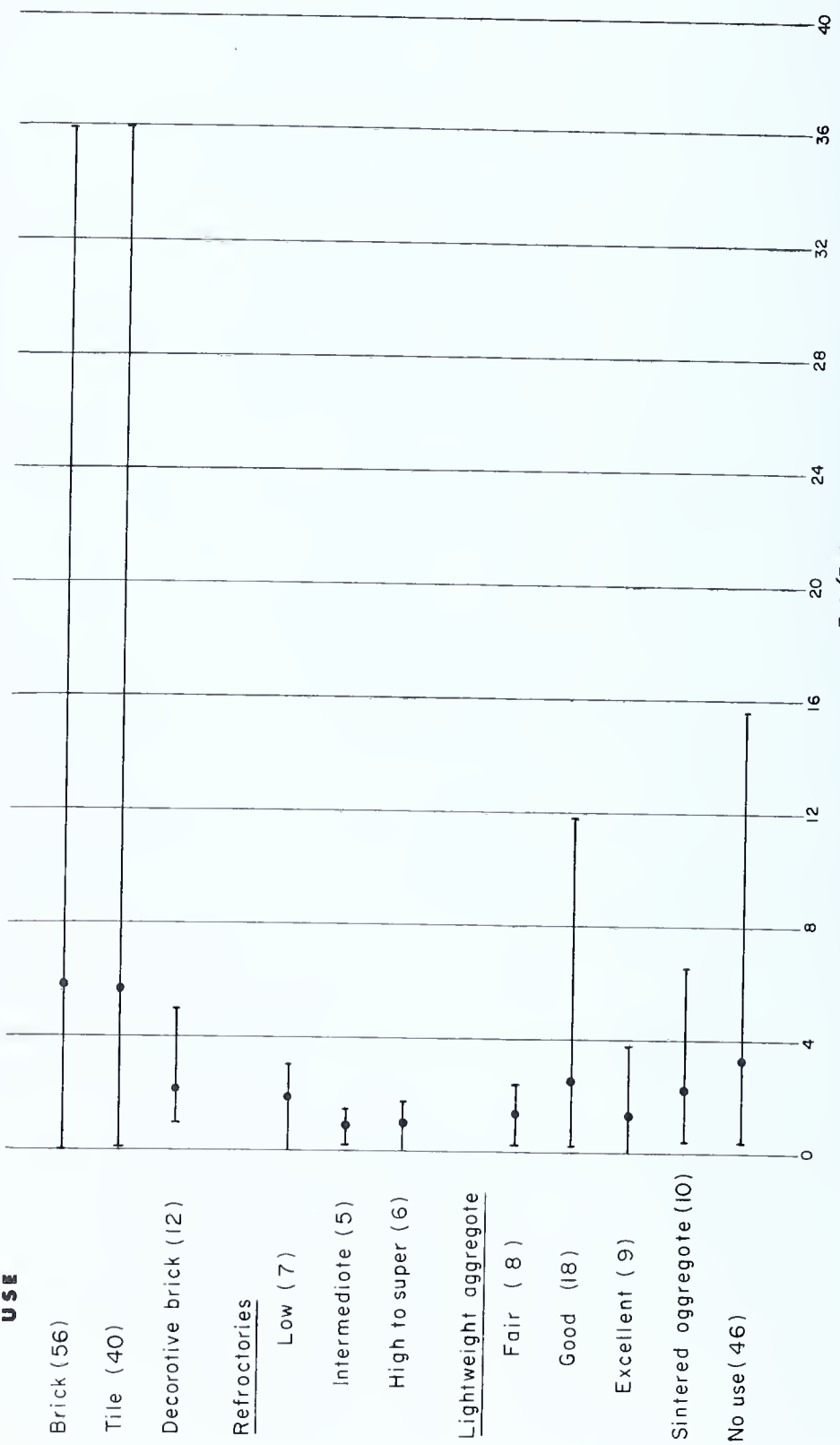


Figure 18. The Fe^3/Fe^2 oxidation ratio versus potential use.

Conclusion.—The empirical relationship between clay-material use and chemical composition is often difficult to explain; many of the relationships offered in this text remain to be explained. However, significant relationships between chemical composition and selected correlative parameters do exist, and this in itself is of considerable value. For example, by using potassium-sodium ratios one should be able to distinguish to a moderate degree between clay materials useful for low-duty refractories and materials useful for intermediate-duty and high- to super-duty refractories. A comparison of K/Na ratios shows that the ratio is noticeably lower for rotary-kiln lightweight aggregate than for brick or tile. With respect to total iron content, there is an upper limit of approximately 2.2 for samples potentially usable as refractories and decorative brick, and a lower limit of about 4.5 for samples potentially usable for all lightweight aggregate. The ratio of ferric iron to ferrous iron for all samples potentially usable as refractories and most samples potentially usable as decorative brick is less than 3.0. (This is in part the result of the low Fe^3/Fe^2 ratio for underclays.) Carbon dioxide is low in refractories and decorative brick, but moderate amounts of CO_2 may be beneficial to lightweight aggregate.

Shrinkage, Plasticity, and pH Correlations

Drying shrinkage, water of plasticity, and pH tests, performed by the U. S. Bureau of Mines were selected for correlation with use and rock type. Both drying shrinkage and water of plasticity are in large part functions of the mineralogy and rock texture and hence they are secondary rather than primary controlling factors. However, from a standpoint of use determination they are usually considered to be important because they influence the structural strength and shape of clay-shale raw materials and products. Rather broad, but critical, limits for specific uses have been established empirically and compiled (Tables 3 and 5) which show a range for drying shrinkage percentages with a maximum upper limit and a range for plasticity values with both lower and upper limits defined, in part, by the required workability of the source material. However, as this report illustrates, the ranges for both these variables and also for pH are sufficiently broad to include the majority of Pennsylvania samples tested and nearly the complete range of potential-use categories. As a consequence, these variables are non-restrictive and generally less useful than a knowledge of the mineral and chemical composition. The pH of a sample is also a secondary factor which is controlled by mineralogy, particle size, and extent of weathering. Those correlations for the three variables which appear to be significant (Fig. 19) are discussed below.

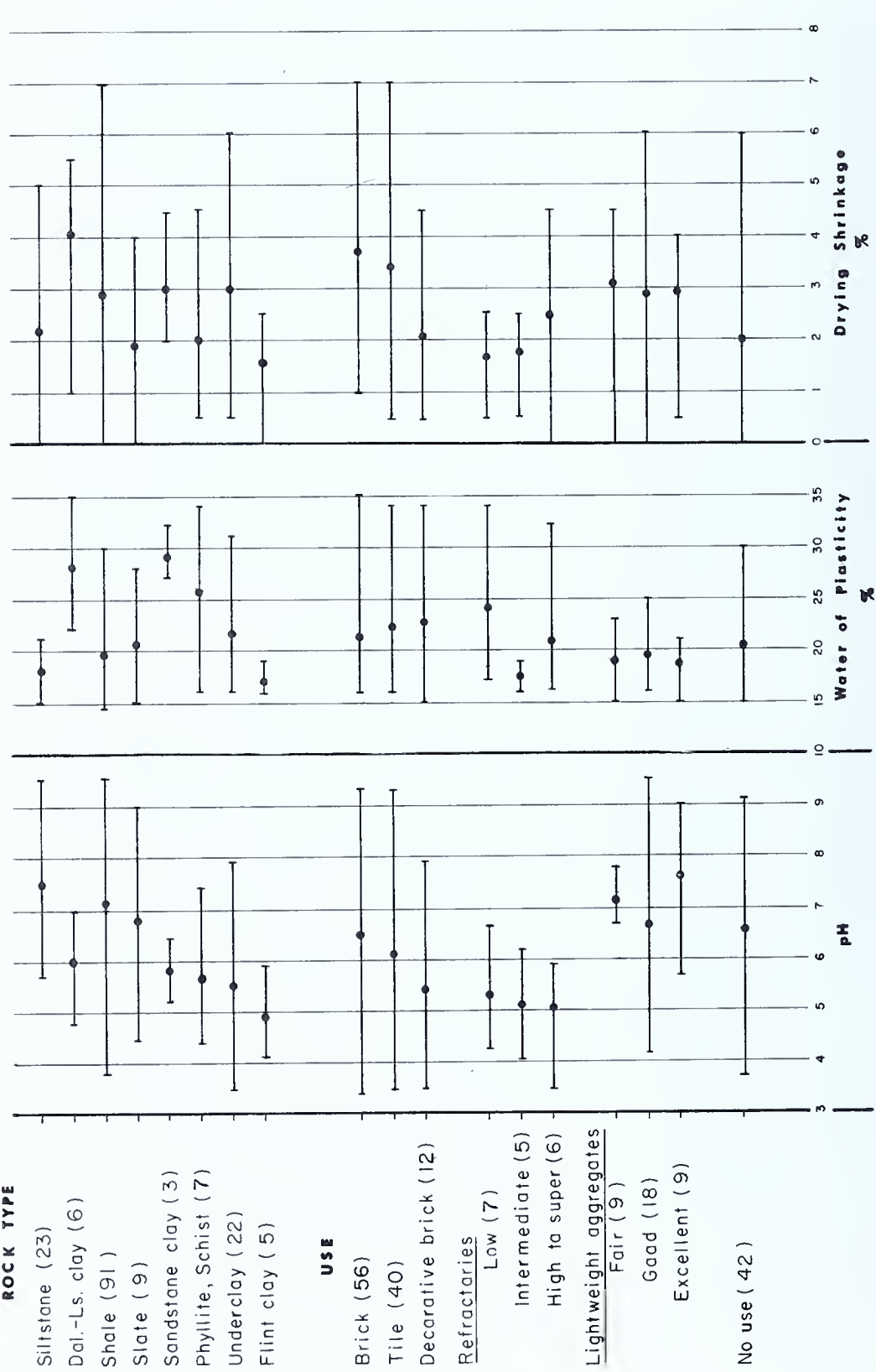


Figure 19. Rock type and potential use versus pH, water of plasticity, and drying shrinkage.

Of the three selected for plotting (Fig. 19), pH illustrates the best control by rock type. Flint clay and residual clays associated with limestones and dolomites have a narrow pH range, and flint clay is further differentiated by low average values. However, in both cases the number of samples is too small to draw definite correlations. The water of plasticity range is short and the average value is low for both siltstones and flint clays. This is one of the few properties which distinguishes siltstones and silty shales from nonsilty shales and is probably related to the increase in quartz content relative to clay minerals. The average water of plasticity percent of residual clays associated with sandstones is high and its range is narrow; however, the number of residual clays associated with sandstones is too small to be reliable. As might be expected from its low water of plasticity, flint clay also exhibits a low average percent drying shrinkage and a narrow range. However, a plot of water of plasticity against drying shrinkage (not shown) failed to reveal a linear relationship, although samples with a high percent drying shrinkage tend to have a high water of plasticity with a narrower range of values than at low shrinkage percentages. Other rock types show a wide range of shrinkage values and are non-restrictive.

Drying shrinkage, water of plasticity, and pH are plotted against potential use in the lower half of Figure 19. The percent drying shrinkage ranges for all use categories overlap and the averages vary only between 1.7% and 3.7%. For refractories, the average percent drying shrinkage increases with increasing grade, probably as a result of water associated with the increasing amount of clay minerals. Refractories and decorative brick tend toward lower average percentages and brick and tiles (excluding chimney flue tile) toward higher percentages. Since the no-use samples average about 2.0%, only those potential uses with higher average percentages can be considered of any practical diagnostic value. The water of plasticity for all grades of rotary-kiln lightweight aggregate is characterized by low average percentages and narrow ranges. It appears to be the only potential use category with a diagnostic percent water of plasticity (the low range for intermediate-duty refractories is suspect because both low-duty and high-to super-duty refractories exhibit a higher average and a broader range). As in the case with the pH-rock type correlation listed above, pH appears to yield the best correlation with use. Rotary-kiln lightweight aggregate is distinguished by a high average pH, and refractories by a low average pH and by a narrow pH range. The pH average for brick and tiles (excluding chimney flue tile) is approximately the same as for no-use samples, and thus is not significant. Decorative-brick correlations are similar to low refractories, but with a somewhat broader range.

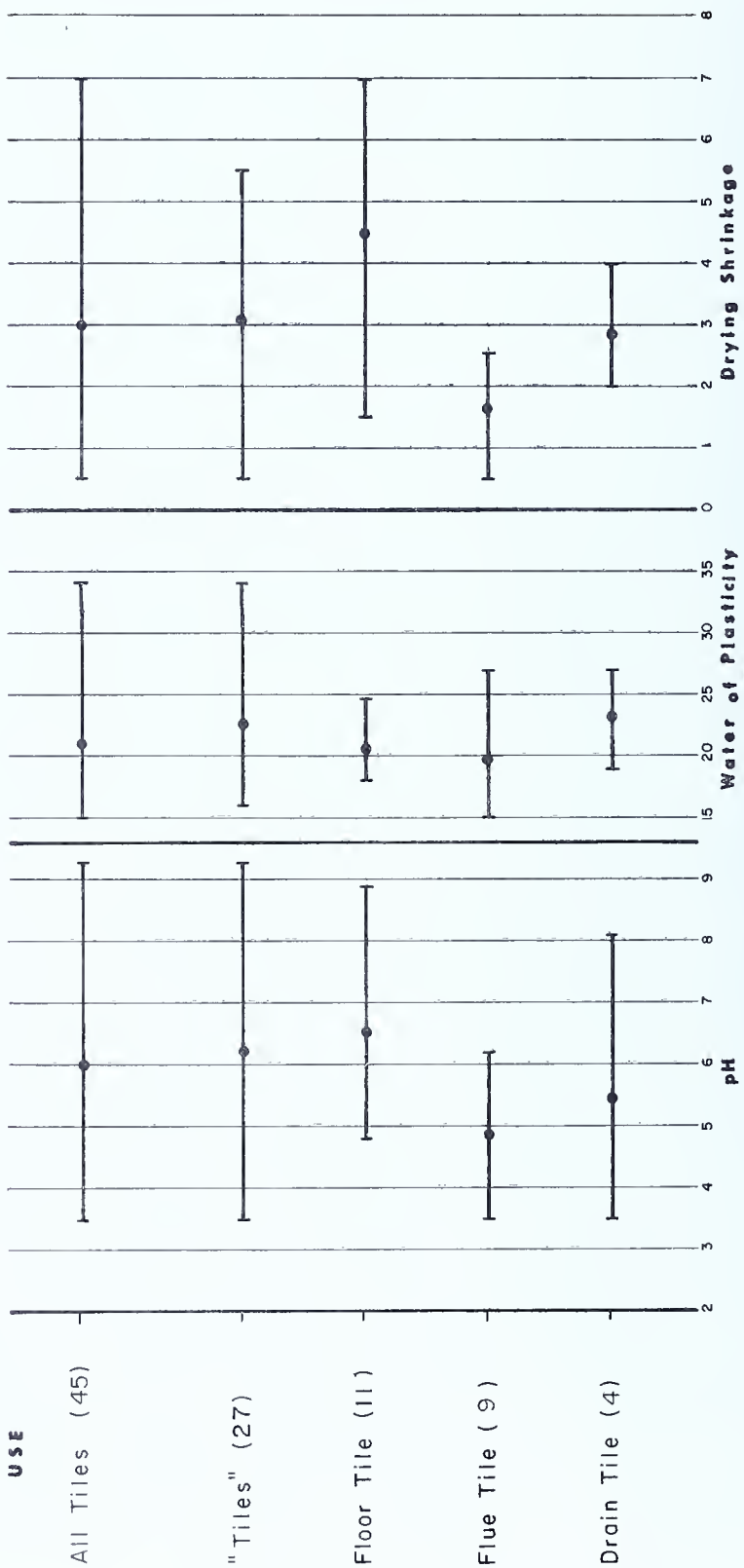


Figure 20. "Tiles", floor tiles, chimney flue tiles, and drain tiles versus pH, water of plasticity, and drying shrinkage.

Several different kinds of tiles were reported by the U. S. Bureau of Mines (see Table 9) which have been grouped under the general heading of "tile" in the previous correlations and discussions. Chimney flue tile was omitted from this grouping because it is more similar in both use and properties to low-duty refractories than to structural tiles. Because previous analytical work (Calver and others, 1961) indicates a difference principally among floor tiles, chimney flue tiles, and drain tiles, these have been plotted separately in Figure 20 against pH, water of plasticity, and drying shrinkage. The category of "tiles" used here (Fig. 20) is that reported by the U. S. Bureau of Mines and is apparently a distinct category. Only two samples were listed with two different potential tile uses and three samples with two questionably potential tile uses. Both pH and percent drying shrinkage exhibit significant variation. "Floor tiles" and "tiles" (structural tile), which are similar to each other, are different from chimney flue tiles and drain tiles (hollow tile) which as a group are also similar to each other. The latter group has a noticeably lower average pH and average percent drying shrinkage and it may be that this difference would be useful in differentiating these two tile groups. Similarly, percent absorption might serve as a distinguishing characteristic, especially between flue and drain tiles (see Table 3). More samples should be tested to confirm these preliminary results. For example, pH may be more dependent on rock type (i.e., a specific rock type use for a specific type of tile) than it is on use. The percent drying shrinkage range, usually given as 0-8% for all these tile types, may actually be divisible into narrower ranges for each type. Similarly, mineralogical and chemical differences may exist within the tile group.

In summary, pH is the most restrictive of the three variables plotted, although water of plasticity may be useful in determining potential rotary-kiln lightweight aggregate. Additional analyses might substantiate the difference in percent drying shrinkage between structural tiles and drain or chimney flue tiles. The ranges used here in conjunction with the mineralogical and chemical correlations (Figures 8, 15-18) can be used to explain the inutility of specific rock types for a specific use (Fig. 13). However, the evaluation of the samples tested generally indicates that measurement of percent drying shrinkage, percent water of plasticity, and pH are not good criteria to differentiate one potential use from another.

SUMMARY

BY D. M. LAPHAM

In the preceding sections a large number of correlations have been discussed, primarily from an empirical viewpoint rather than from the

aspect of any fundamental interaction between primary variables. Many of these correlations should be potentially useful in the search for economically valuable deposits of shales and clays, and it is the objective here to briefly recapitulate those which can best be used to evaluate a shale or clay occurrence. The authors wish to emphasize that the correlations and resulting conclusions are based only on data presented in this report and may require modification after more detailed and widespread studies are completed. In several cases, the correlations are severely limited by the number of samples examined; for example, only a few samples from the middle Kittanning shale, but a very large number of Martinsburg Formation samples were studied, so that relative evaluations of these two shale units for a specific use must await additional research. Regardless of the reliability of any one correlation for predetermining use, the actual determination procedure will also depend on other factors such as methods of product manufacture, economic consideration, and availability of instruments for testing. In the final analysis, these correlating parameters will be useful only to eliminate certain samples from consideration. The remaining samples probably will always have to be tested for fulfillment of the particular use requirements desired by making a pre-production experimental product.

In general, the type of raw material is the most important variable and the first one which should be considered in the exploration for economically valuable shales and clays. The other important variables, in decreasing order of significance, are mineralogical content, chemical composition, and pH, water of plasticity, and drying shrinkage, However, complete analyses are not needed to evaluate samples for a particular use. The specific variables found to be significant for the different uses in this study are presented in more detail in Table 13, listed in order of decreasing importance. This estimated order is derived from previous correlations, in that the more restrictive is the correlation, the more significant is the measurement for predicting a specific use. None of the restrictions listed in Table 13 can be used by themselves to determine use. They are not all-inclusive, but merely guides which could be used in a step elimination process. There are few criteria that distinguish potential materials for brick and tiles from no-use samples because these products will tolerate wide ranges of nearly all the variables measured. Possibly an analysis for multiple interdependence of these variables would yield more significant correlations. Decorative brick, which is similar to the lower temperature refractories in terms of determinative characteristics, has several usefully restrictive parameters, whereas higher temperature refractories and rotary-kiln lightweight aggregate have the largest number of restrictive parameters. Because many lightweight aggregates are produced from shales, their differentiation from potential

Table 13—*Analytical variables for determining the use of unfired shale-clay materials. Listing is by estimated order of importance.*

Brick	*Tiles*	*Decorative Brick*	*Fire Clay Refactories*	*Lightweight Aggregate*
1. Low kaolinite content (<20%).	1. Probably a minimum kaolinite content especially for specific tile types.	1. Potentially useful rock types: light-colored underclay and residual clay.	1. Potentially useful rock types: flint clay and other underclays.	1. Potentially useful rock types: shale and slate.
2. Potentially useful rock types: shale, residual clay, underclay, and slate.	2. Potentially useful rock types: shale, residual clay, and underclay.	2. Maximum mica content of approx. 40%, and a narrow range (avg. 20-30%).	2. High kaolinite content, increasing with increasing temperature grade.	2. A narrow quartz range (25-48%).
3. (?) A minimum quartz content of approx. 20%.		3. Low total fe (<2.2%) and low CO_2 (<2.1%).	3. Low mica (10-40%) and C-V-Mo* (<5%).	3. A minimum total Fe (4.5%); a low, narrow range for water of plasticity (15-25%).
		4. Low Fe^3/Fe^2 (<2.5-3.0).	4. Low pH (<6.5) of clay source material.	4. Low kaolinite content (avg. 5-10%); minimum C-V-Mo* (avg. 5%) of 1-2%, and moderate CO_2 (up to approx. 6%).
			5. Low total Fe (<2.2%) and CO_2 (<2.0%).	5. A lower K/Na (2.0-7.0) than for shales usable for brick and tile.
			6. Low Fe^3/Fe^2 (<2.5-3.0), low K/Na (<7 and avg. = 3) for intermediate and higher grades.	

* C-V-Mo: Chlorite, vermiculite and montmorillonite.

brick and tile shales (Table 13) may be quite important. Additional research in this direction might prove very useful.

In addition to the criteria presented in Table 13, several features of the correlations are noteworthy. Both brick and tile raw material have a very wide Fe^3/Fe^2 tolerance range. This can be interpreted to mean that weathered as well as unweathered shales are potentially useful. Weathering may have a more pronounced effect on the utility of materials for rotary-kiln lightweight aggregate, but the data are insufficient to support definite conclusions. In addition to the positive criteria in Table 13, the inutility of a particular sample for a specific use can often be explained because one or more of the variables lies outside the range illustrated in the correlation graphs. For example, samples not usable for decorative brick frequently have too high a mica, carbonate, feldspar, or chlorite-vermiculite-montmorillonite content. Kaolinite, on the other hand, may be too low. The same qualifications apply to fire-clay refractories. Exclusion of samples for potential rotary-kiln lightweight aggregate results from an excess of quartz or kaolinite, and a deficiency of mica or chlorite-vermiculite-montmorillonite. In addition, the percent water of plasticity may be too high or the pH of the raw material too low. Samples which have a high firing temperature, and hence a great amount of kaolinite, will be excluded from use as a brick, although they may be useful for decorative brick if color requirements are met. However, no samples were found that tested as potentially useful for both ordinary brick and decorative brick. This exclusion may be a consequence of the use definition, i.e., if the color is sufficiently pleasing for decorative brick, it will be preferred for that use rather than for the more easily obtained ordinary brick, and hence will not be listed for both brick uses. Although there are few properties which will exclude samples either from the brick or tile use categories, parameter averages and an approximately 1:1 ratio of mica to quartz, may represent optimal use values.

This report differs from most previous shale-clay resources surveys (see References) in several important aspects. Although chemical and physical properties tests are commonly used to supplement use data obtained from laboratory testing, the quantitative correlations presented here are an attempt to set maximal and minimal limits upon each variable. Ideally this procedure should be augmented to include the interdependence of several variables upon a particular use and to include more detailed field sampling and testing of geologic units and rock types. Until such an expanded program is completed all such correlations must remain somewhat tentative. Also different is the method of quantitative X-ray mineral analysis and the use correlations drawn from them. These data are especially welcome for potential rotary-kiln lightweight aggregate samples

because the controlling factors in their utility have not been well known because of the difficulty of applying accurate quantitative mineralogy to fine-grained shales and clays with respect to use. Mineral composition often has been assumed to be a major controlling variable in some use categories (Conley and others, 1948, p. 16, 30) largely as a result of a lack of any good correlation with other kinds of tests. From the initial studies presented here, this conclusion seems only partly warranted; although mineralogy may be a more important variable than, for example, chemical composition, it is not the cure-all for use determination that had been hoped for. The final answer probably lies not in any one type of parameter measurement, but in combining several, including such factors as extent of weathering, rock texture, color, and grain size.

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C24-56 *Test for pyrometric cone equivalent (PCE) of refractory materials*
C27-60 *Classification of fireclay and high-alumina refractory brick*
C29-60 *Test for unit weight of aggregate*
C32-63 *Specifications for sewer brick (made from clay or shale)*
C34-62 *Specifications for structural clay load-bearing wall tile*
C43-55 *Definitions of terms relating to structural clay tile*
C55-55 *Specifications for concrete building brick*
C56-62 *Specifications for structural clay non-load-bearing tile*
C57-57 *Specifications for structural clay floor tile*
C62-62 *Specifications for building brick (solid masonry units made from clay or shale)*
C71-63 *Definitions of terms relating to refractories*
C90-59 *Specifications for hollow load-bearing concrete masonry units*
C112-60 *Sampling and testing structural clay tile*
C126-62 *Specifications for ceramic glazed structural clay facing tile, facing brick, and solid masonry units*
C127-59 *Test for specific gravity and absorption of coarse aggregate*
C129-59 *Specifications for hollow non-load bearing concrete masonry units*
C134-41 *Test for size and bulk density of refractory brick*
C135-47 *Test for true specific gravity of refractory materials*
C140-62 *Sampling and testing concrete masonry units*
C145-59 *Specifications for solid load-bearing concrete masonry units*
C154-41 *Test for warpage of refractory brick and tile*
C155-47 *Classification of insulating fire brick*
C180-52 *Panel spalling test for fireclay plastic refractories*

C181-47 *Test for workability index of fireclay plastic refractories*
C212-60 *Specifications for structural clay facing tile*
C216-62 *Specifications for facing brick (solid masonry units made from clay or shale)*
C242-60T *Definitions of terms relating to ceramic whitewares and related products*
C261-60T *Specifications for standard strength unglazed clay pipe*
C278-60T *Specifications for extra strength unglazed clay pipe*
C301-60T *Testing clay pipe*
C322-56 *Sampling ceramic whiteware clays*
C323-56 *Methods for chemical analysis of ceramic whiteware clays*
C324-56 *Test for free moisture in ceramic whiteware clays*
C325-56 *Test for wet sieve analysis of ceramic whiteware clays*
C326-56 *Determination of drying and firing shrinkages of ceramic whiteware clays*
C329-56 *Test for specific gravity of fired ceramic whiteware clays*
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GLOSSARY

Absorption The relation of the weight of water absorbed by a specimen to the weight of the dry specimen, expressed in percent.

Binary correlation Any correlation between two variables such as the range of quartz content plotted against samples potentially useful for low duty refractories.

Bloating Expansion produced by heat that causes the formation of a vesicular (cellular) structure.

Bloating range Temperature range in which a clay material will bloat.

Channel sample A sample collected continuously along a relatively long distance but narrow width (oriented normal to bedding in this program).

Clay minerals Used here to designate kaolinite and the collective group of chlorite-vermiculite-montmorillonite; does not include mica.

Claystone An indurated clay.

Composite sample A sample containing more than one type of rock, but representative of the proportion of the different rock types in the exposure.

Empirical Depending upon observation and experience without regard to theory.

Fatty Smooth and highly plastic, unctuous, at room temperature.

Firing Heating of a sample as in a muffle or rotary kiln furnace.

Firing Range Range of firing temperature within which a ceramic composition develops properties which render it commercially useful.

Flint clay A hard brittle underclay lacking plasticity.

Fusion The process of surface melting resulting in a glassy phase causing particles to stick together.

Glaze Glassy surface caused by fusion or melting.

Grab sample A sample collected at uniform intervals along an exposure or over a stockpile.

Gritty Presence of coarser hard particles (grit); grittiness.

Illite Fine-grained muscovite mica often slightly deficient in potassium and sometimes poorly crystalline; frequently a weathering product of primary or better crystallized muscovite.

Indurated A term applied to rock hardened by heat, pressure, and cementation.

Interference, mineral Used in this report to describe the superposition of X-ray reflections from two or more minerals on an X-ray diffraction chart and rendering the differentiation of these minerals difficult.

Lightweight aggregate Aggregate prepared by expanding or sintering clay, shale, and slate. In this report, the term refers primarily to lightweight aggregate produced in a rotary kiln.

Line broadening Used in this report to refer to the broadened peaks on X-ray reflections from a particular atomic spacing, or related group of spacings. It is a measure of degree of crystallinity and particle size.

Mealy Granular feel caused by lumpy, soft particles.

Metamorphic rock Rock which has formed in response, to pronounced changes of temperature, pressure, and chemical environment, exclusive of weathering.

Phyllite An argillaceous rock intermediate in metamorphic grade between slate and schist. The mica crystals impart a silky sheen to the surface of the cleavage (or schistosity).

pH value Measurement of acidity or alkalinity.

Plasticity That property of a material that enables it to be molded into desired forms, which are retained after the pressure of molding has been released.

Point of release The time at which the bloated aggregate fell off the wall of the rotary kiln, i.e. 11:00 a.m.

Possible potential A sample of questionable potential utility.

Preferred orientation Used in this report to designate a parallelism of platy minerals which enhances certain X-ray reflections.

Pyrometric cone equivalent (PCE) A measure of the refractories of a material, expressed in terms of standard pyrometric cones. More precisely, the number of that standard pyrometric cone whose tip would touch the supporting plaque simultaneously with a cone of the refractory material being investigated.

Quick-firing Process of firing a dried sample in a muffle kiln which is at an actual firing temperature and keeping the sample in the kiln for 15 minutes.

Refractoriness The capacity of a material to resist fusion or vitrification at high temperatures. In ceramics, the property of resistance to melting, softening or deformation at high temperatures. For fire-clay materials the most commonly used index of refractoriness is that known as the PCE.

Restrictive correlation A correlation between two or more variables which is significant because it is limited in the following ways:
1) by a narrow range whose limits are well defined
2) by a range which differs considerably from other ranges for the same variable in a binary correlation.

Rotary-kiln aggregate Expanded aggregate made in a rotary kiln.

Schist 1) A medium or coarse-grained metamorphic rock with sub-parallel orientation of the micaceous minerals which dominate its composition
2) Rocks which have a foliated structure, split up in thin, irregular plates, not by regular cleavage as in clay slate, nor in large flat laminae, as in flagstones

Scumming Formation of undesirable coating on surface of fired ceramic material.

Shrinkage A volume reduction of a ceramic material during drying or firing, measured linearly.

Siliceous clay Clay sized particles high in quartz, not lithified.

Sintered aggregate Expanded or porous aggregate made by sintering.

Slate A fine-grained metamorphic rock possessing a well-developed fissility (slaty cleavage).

Slow firing Process of firing dried samples in a muffle kiln started from room temperature and raised to maximum temperature in several hours and removing a sample at each predetermined temperature.

Slow Firing Test (hardness) Soft—(scraped by fingernail)
Fairly hard—(scratched by nail)
Hard—(scratched by knife)
Very hard—(scratched by metal file)
Steel hard—(not scratched by metal file)

Specific gravity The ratio of the weight of a unit volume of a substance to the weight of an equal volume of water. True specific gravity is based on the volume of the solid material, excluding all pores. Bulk specific gravity (BSG) is based on the volume as a whole; i.e., the solid material with all included pores. Apparent specific gravity (ASG) is based on the volume of the solid material plus volume of the sealed pores.

Stoichiometric composition The ideal chemical composition of a substance according to its formula composition.

Strength Ability to withstand handling. Same as dry or green strength.

Structural clay products Products made chiefly of clay which are used by the building trades and in non-residential construction.

Till Nonsorted, nonstratified sediment carried or deposited by a glacier.

Underclay A stratum of clay beneath a coal bed often containing roots of coal plants, especially Stigmaria; includes flint clay.

Water of plasticity Percentage of water added to dry clay to make it plastic; Atterberg test.

Workability Ability to be worked or formed by hand, tested mainly by plasticity.